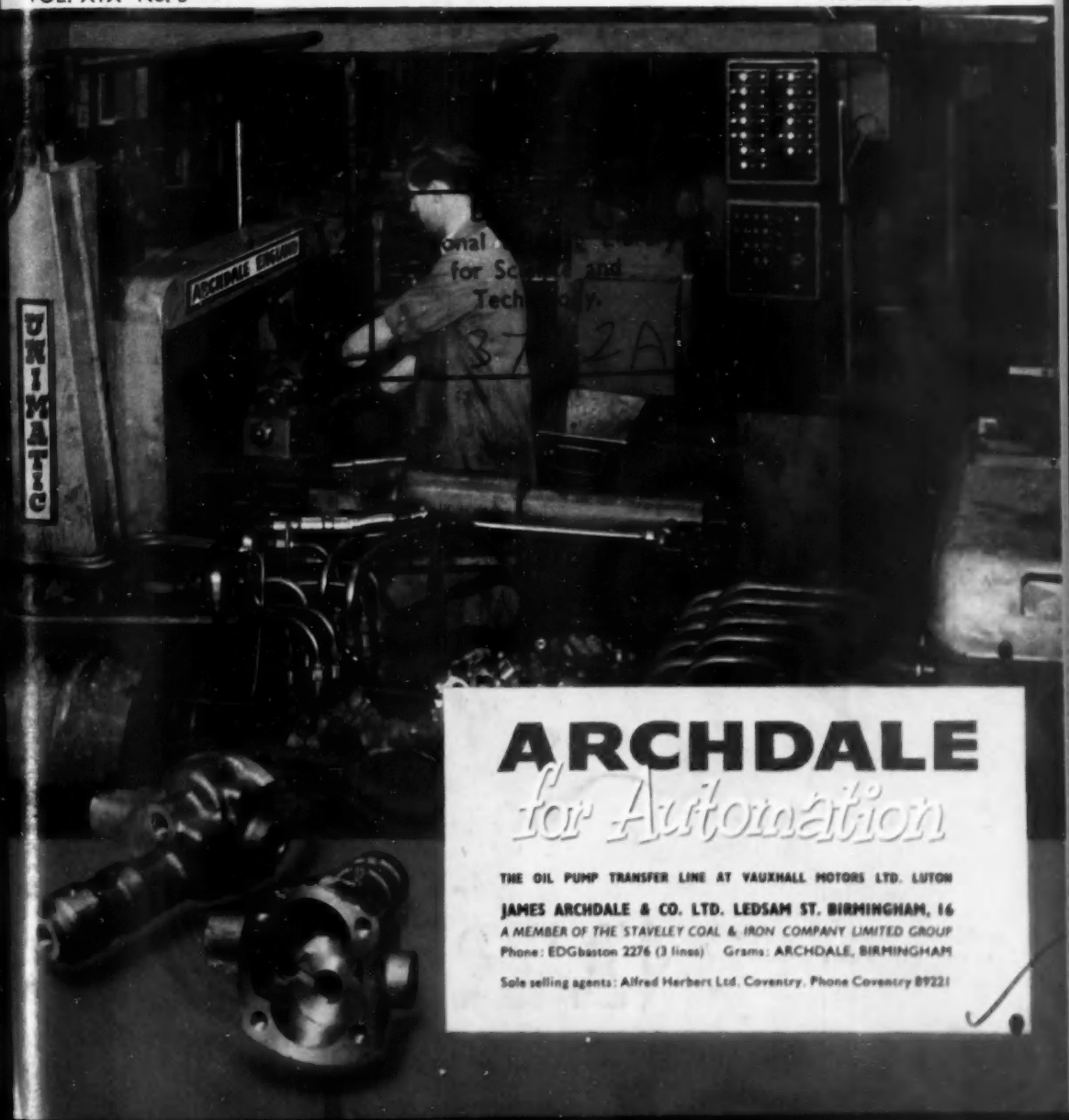
The ENGINEERING DIGEST

ENGINEERING DIGEST:
[illegible]

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XIX No. 8 AUGUST, 1958



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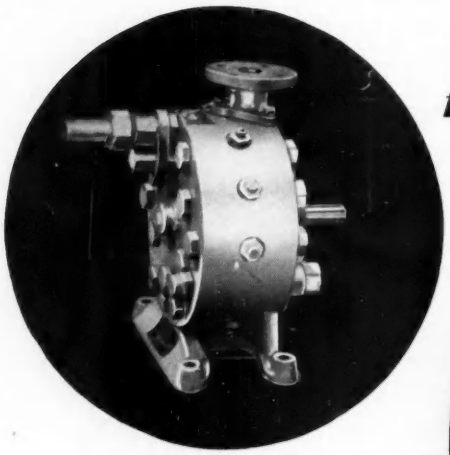

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Rotary positive displacement pump of high volumetric efficiency.

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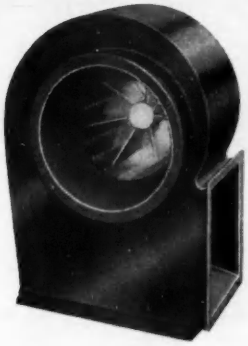

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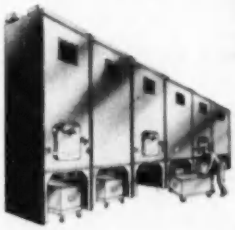
The "Resista" P.V.C. Fan is impervious to the chemical action of strong acids, alkalis and moist gases. It is the fan that in conjunction with P.V.C. Hoods and Ducting has provided industry with the greatest step forward in chenical fume handling.



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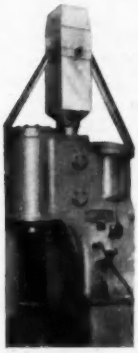
"Airflo" 'E' Type Dust Collecting Unit. For dry non-fibrous, non-explosive dusts with air temperature not exceeding 160°F. Fully automatic shaking device. Made on unit principle.



INDUSTRIAL SILENCING

Where noise creates problems as with Drop Stamps, High pressure blowers, Air noises on Dust and Fume Plants, especially during night shifts the purpose designed "Airflo" Industrial Silencer provides the easy solution. Simple to install. No loss of production efficiency.

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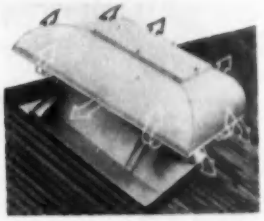

"Airflo" Powered Roof Ventilator. Fits any roof angle. Light enough for corrugated iron roof. *Positive* ventilation under all conditions. Unit despatched completely assembled. Prices from £29 15*s*.

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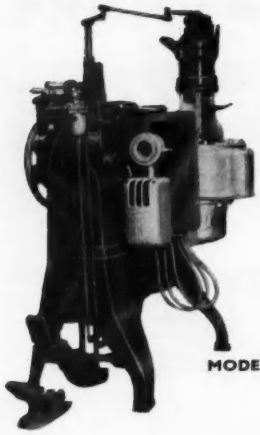

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A shot every moment
—cast well and true,
with production improvement
means business for you

MODEL 500

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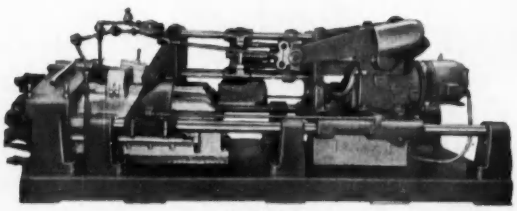
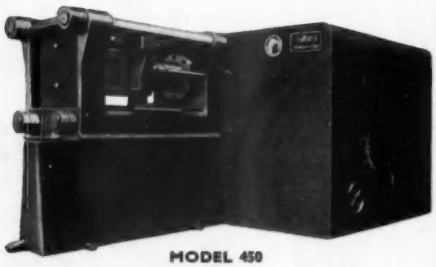


MODEL 4



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PRODUCTION'S MUCH FASTER WITH A COULTHARD-KIPPCASTER.

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Fractionals

put power where you want it

Power for many purposes. Power to drive your own plant efficiently, or to add further distinction to the equipment you make and sell. Power. As much (up to 1 h.p.) or as little as you need, in a wide range of mountings, but always with the reliability for which all G.E.C. engineering is famous. Power, from sturdy, dependable G.E.C. Fractionals. Most sizes and mountings are held in stock—that's another advantage of dealing with the G.E.C.

G.E.C. manufacture many types and sizes of fractional motors for light industrial and domestic drives—whether for your plant or products our engineers will always be pleased to help you choose the right motor for the job.

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PLANO-MILLING MACHINE

Capacity 6 ft wide x 6 ft high x 18 ft long. Infinitely variable speeds and feeds.

• More Power
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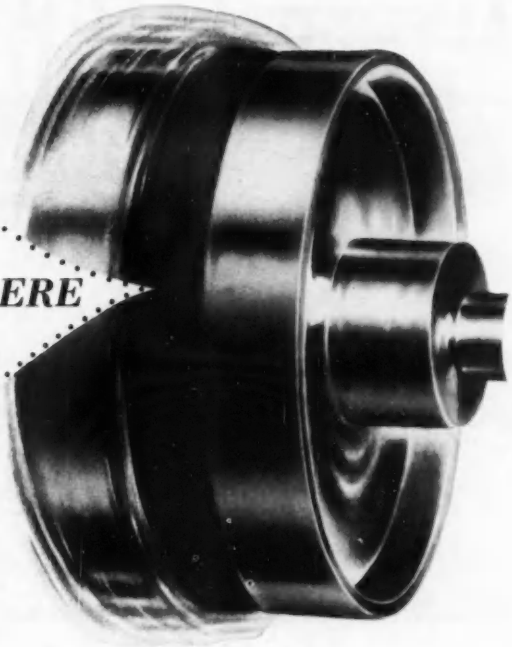
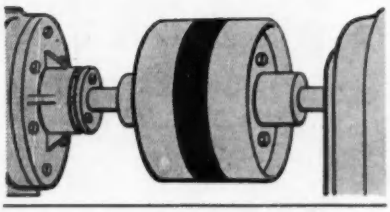
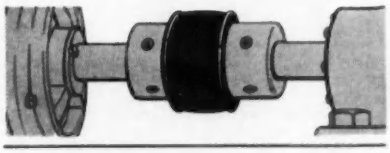


When machines must operate under load fluctuation or conditions of misalignment

DUNLOP *FLEXIBLE COUPLINGS HELP SMOOTH WORKING*





Dunlop Couplings consist of flexible rubber elements bonded to metal ends. The rubber can be compounded with varying degrees of stiffness as required by the task the coupling has to do, but the physical properties are always controlled within fine limits. Dunlop Flexible Power Transmission Couplings can be used with confidence in applications where precision is vital.

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For heavier equipment, operating at up to 96 h.p. per 100 r.p.m.

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For light machines and motors, operating at up to 0.54 h.p. per 100 r.p.m.

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REWIREABLE FUSE LINKS

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Offer Advanced Characteristics

This range of Aeroflex Fuses has a proved breaking capacity of 46 KA and a standardised fusing factor of 1.25. Known as the AD and FC types, they are fully interchangeable with their predecessors, the AF and CM patterns, and, of course, they are rewireable—fuse links are not discarded when blown, they can be returned for prompt replacement in our rewiring service scheme. *Send for Publication CF.2.*

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Made in various sizes, tough, flexible and light in weight. Self-locking, with radiused inner surface. Earthing or Plain types available in Saddle or "P" form.

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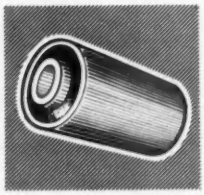
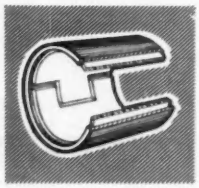
Ideally suited for all sealing purposes, absorbing vibration and weather sealing. Easy to apply and economical in use. Over 50 different sections available and supplied in 10 ft. rolls.



'CLAYFLEX'
FLEXIBLE BEARINGS

Provide for the silent transmission of power and eliminate vibration. They cushion drive and require no lubrication, adjustment or maintenance. Produced in a variety of styles and sizes. Our Technical Dept. will gladly advise on bearings to meet your particular application.



'NYLASTIC'
BEARINGS

For oscillating and rotary applications these bearings are designed to bring users the full benefit of Nylastic as a bearing material. Having a relatively low coefficient of friction, Nylastic provides a smooth silent bearing that can operate under the most adverse conditions.

For further details of these and other products write to Dept. E.D. 7.

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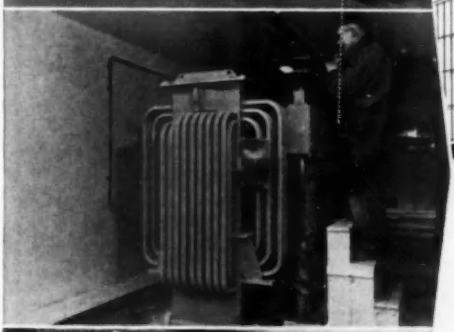
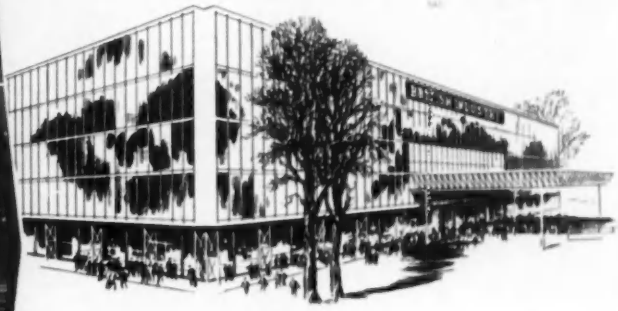
'ENGLISH ELECTRIC'
distribution equipment chosen for the British Industries Pavilion at Brussels



Some of the 'ENGLISH ELECTRIC' equipment being installed in the sub-station



The main substation controlling power and lighting throughout the British Industries Pavilion is equipped entirely by 'ENGLISH ELECTRIC'.

This substation has a capacity of 1,000 kVA, taking its supply from a ring main through a six-panel type OLX high voltage switchboard. Two 500 kVA, 11,000/415 volts, 50 cycles transformers feed on to a 'Superform' medium voltage switchboard comprising two 800 amp. type OB.23 air circuit-breakers and 22 outgoing H.R.C. fuse switches. Like the Pavilion itself, the 'ENGLISH ELECTRIC' substation is virtually a glass showcase where millions of visitors will be able to see the most modern electrical control equipment in actual use.

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

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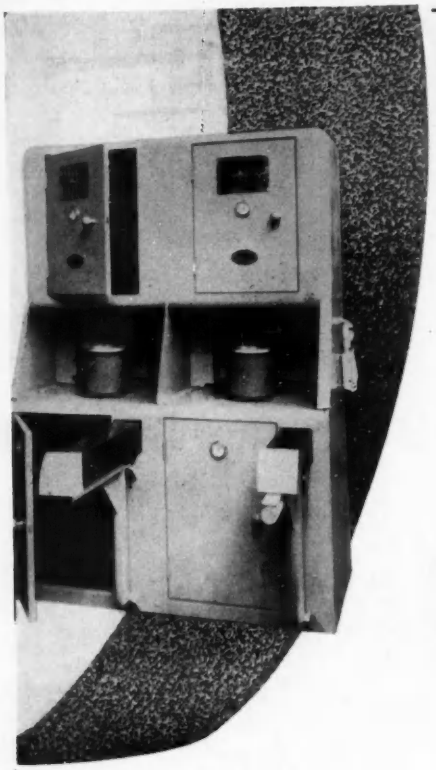


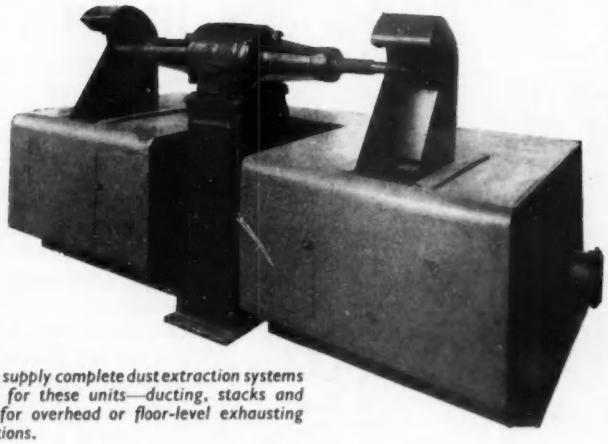
MOP DRESSING CABINETS

Normally the equipment required to coat with abrasive grit different kinds of mops consists of separate units, i.e., emery troughs, glue-pots and heaters, curing and drying cabinets, etc., but with these mop dressing cabinets all necessary requirements are contained in one compact assembly.

Heating can be effected either by steam or electricity, and thermostatically controlled in curing, drying and glue-pot sections. This is an essential item where super finishes are required.

POLISHING BENCHES

These are ideal polishing Benches for small or medium sized components. Note the strong hoods, with ample adjustment provided ; the absence of ledges and sharp corners ; flush doors to operator's cupboards, and a large clear area for component storage.



We also supply complete dust extraction systems suitable for these units—ducting, stacks and filters—for overhead or floor-level exhausting installations.

A. E. GRIFFITHS (SMETHWICK) LTD. BOOTH STREET, BIRMINGHAM, 21.

for the world's finest electric shaver . . . only the best is good enough

But in this fiercely competitive market, it must be more than merely efficient—it must look efficient, and attractive. That is why Sunbeam, when they first discussed the mouldings for the new Shavemaster with us, insisted on perfection in finish.

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Absolute dimensional accuracy, perfect alignment of the contours of all moulded components, absence of sharp edges which might scratch the face—these were just a few of the qualities insisted upon. Acetate Butyrate was selected as the moulding material. It has a warm feel, lends itself admirably to both "leatherette" tooling or smooth finish and has excellent dimensional stability. Your enquiries would be welcomed.

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the plastic moulders with the engineering background

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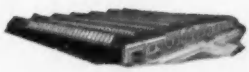
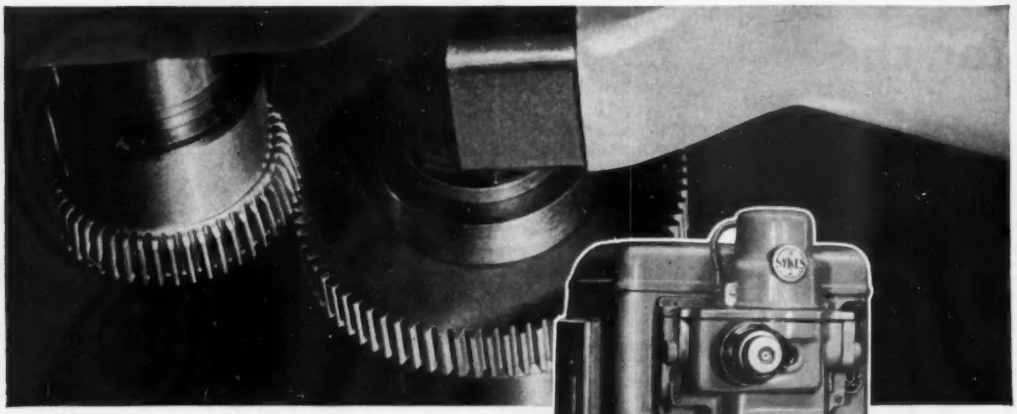


Walsall Works (Bescot Crescent)

Walsall Works (Eldon Street)

Cheapside Works



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W. E. Sykes Ltd. — specialists for more than 30 years in the design and manufacture of machines and tools for gear production — invite a closer look at the model V4 fine pitch gear shaper. Especially suitable for producing fine pitch gears up to 4 inches in diameter and from 16 to 100 D.P. for use in instruments and intricate mechanisms, the precision model V4 will produce with equal accuracy external and internal spur gears, helicals, sprockets, serrations, ratchets and many intricate profiles. Tooth to tooth and total composite errors of gears generated are guaranteed to be within the Admiralty Class 1 specification ' Precision Gearing for Control Systems '.
Fullest details and descriptive literature are freely available, together with the experience of the Sykes Technical Advisory Service.

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Spiral Bevel and Hypoid Gears from 1" to 72"

Spiral Bevel and Hypoid Gears offer many advantages for right angle drives where high efficiency, smooth and silent running are required. E.N.V. specialize in the design and manufacture of straight and curved tooth bevel gears. They offer collaboration with engineers from the project stage on the design of gears and mountings. They have unique facilities for the large-scale manufacture of transmissions including final drives, differentials and axles for vehicles and agricultural equipment, precision gears for aircraft and gears for industrial applications.

ENV *for gears*

E. N. V. ENGINEERING COMPANY LIMITED *HYTHE ROAD, WILLESDEN, LONDON, N.W.10*

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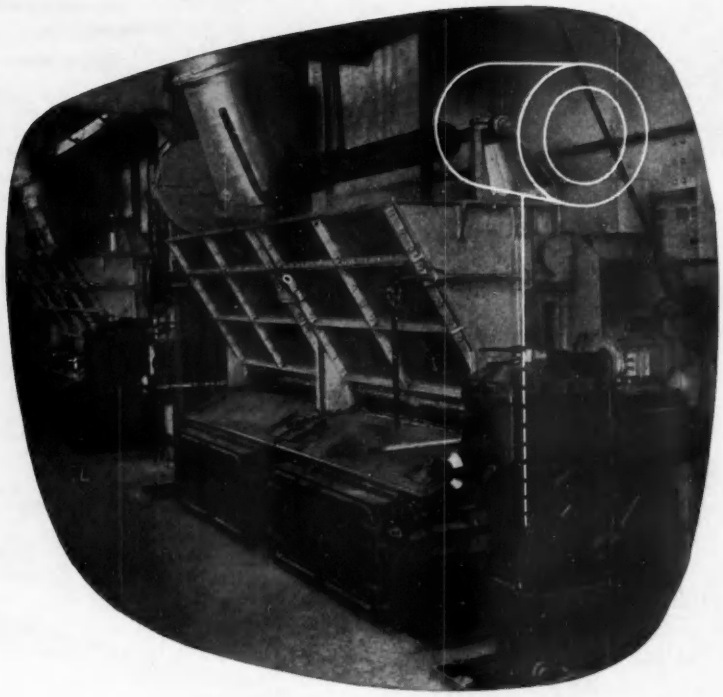
NO MAINTENANCE—



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These Travelling-Grate Stokers made by Babcock & Wilcox supply annually 22,000 tons of coal to boilers which in turn supply the entire steam requirements of the large heavy-chemical works of Dorman Long. MORGANITE CARBON BEARINGS situated in the hot zone have to withstand severe treatment.

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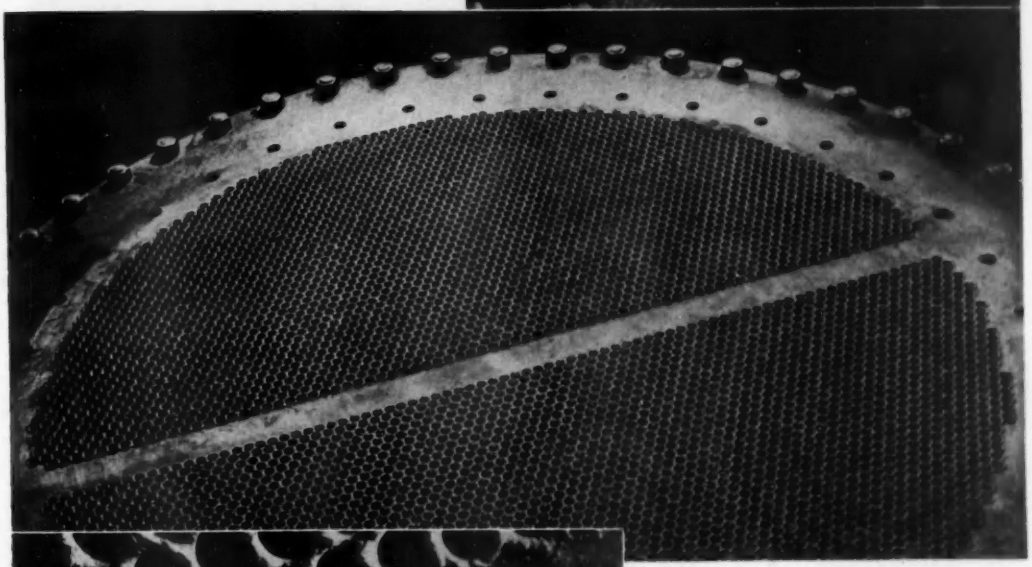

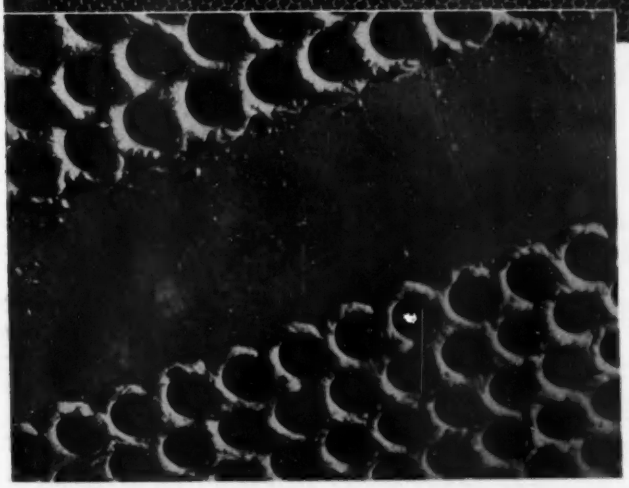

Tube plate for a Heat Exchanger, incorporating 5,518 tubes ¾ in. dia., and involving 1,078 footage of welding.

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CASE HISTORY No. 101

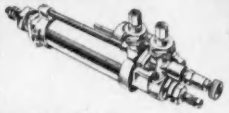
AIR HYDRAULIC POWER PACKS IN PARALLEL

BRITISH BELLOWS

"DO IT YOURSELF" AUTOMATION

BEFORE
200
PER OPERATOR/HOUR

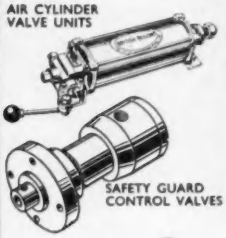
AFTER
415
PER OPERATOR/HOUR



HYDRAULIC CHECK CYLINDERS WITH SKIP AND STOP CONTROLS LIGHT & HEAVY DUTY & DOUBLE ACTING

ROTARY FEED TABLES

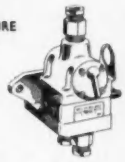
AIR CYLINDER VALVE UNITS

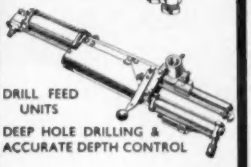


SAFETY GUARD CONTROL VALVES

ELECTROAIRE VALVES

8 VOLTS. 3 SIZES

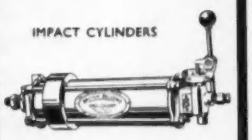




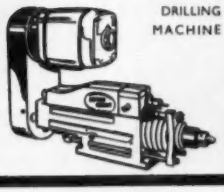
DRILL FEED UNITS

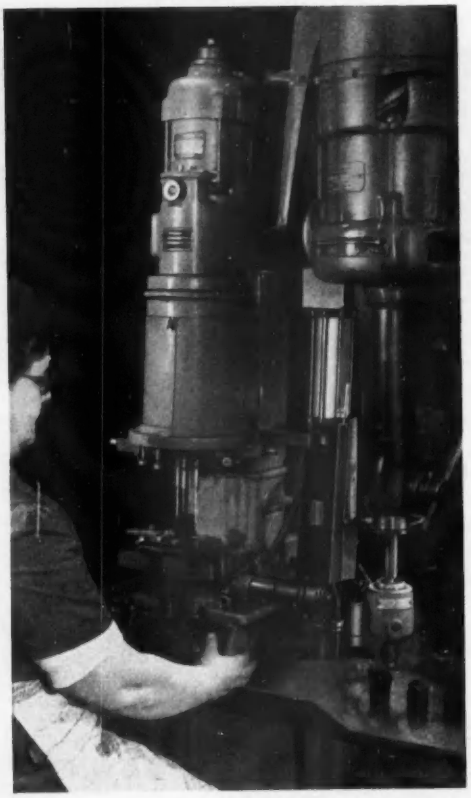
DEEP HOLE DRILLING & ACCURATE DEPTH CONTROL

IMPACT CYLINDERS



BELLOWS-LOCKE UNIT DRILLING MACHINE





British Bellows Controlled Air Power Equipment is specifically designed to speed up production and save labour costs. It can be fitted by your own staff—to new or existing machinery.

Photograph by courtesy of Witton Moulded Insulation Works G.E.C.

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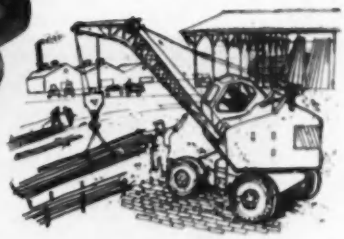
Manufactured by the British Bellows Division of GEO. H. HUGHES LTD., Edgemond Avenue, Birmingham 24. Tel. : ASHfield 1183.



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*** A SUGGESTION FOR MACHINE MANUFACTURERS:—**
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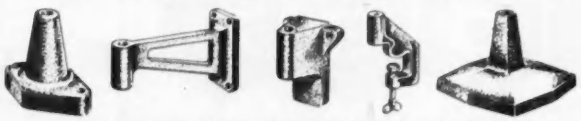
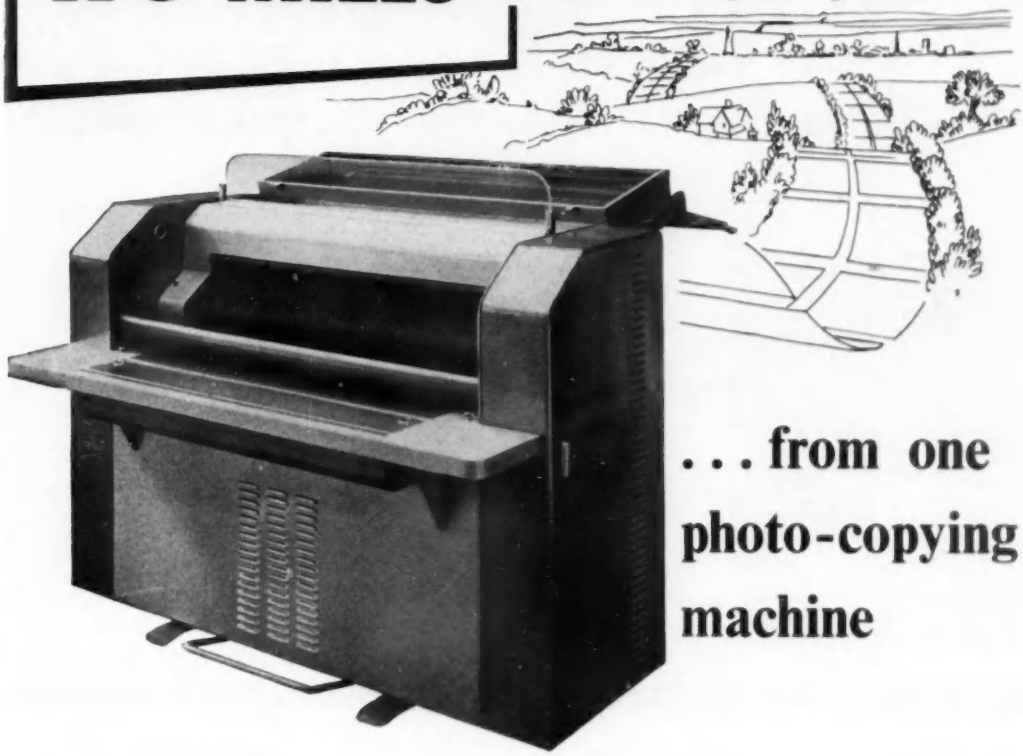


Some of the alternative bases for all models

HT20B

175 MILES *of prints per year...*



...from one photo-copying machine

175 miles of prints a year is the output reported by one regular user of an Azoflex Model 46/35—and that's the sort of output that any busy drawing office can expect. The AZOFLEX photo-printing process combines several unique features. It's the *only* daylight reflex copying process. It's the *only* process to apply a measured quantity of developer irrespective of running speed, thus ensuring optimum quality. It avoids the use of dangerous chemicals and there are no unpleasant fumes. Operation is quiet and free from vibration. Exposing, developing and print delivery are all synchronised to ensure an even flow of finished work at all speeds.

AZOFLEX MODEL 46/35 combined synchronised printer and developer. Capacity: cut sheets and rolls up to 42 in. wide. Printing speed: up to 30 ft. per minute. Dimensions: Height 58 in. Depth 60 in. Width 72 in. Weight 1,100 lb. Price £1,555 (including delivery and installation in the U.K.).

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Enquiries to: Ilford Limited, Industrial Sales Dept. AZ11U
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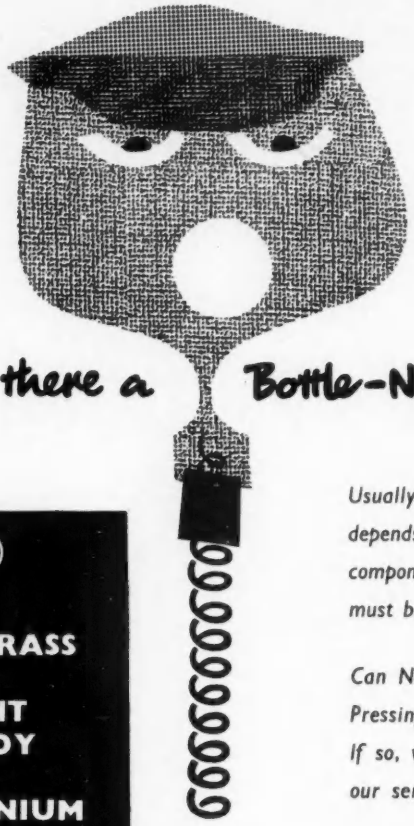
PHOTO-PRINTING MACHINES AND MATERIALS



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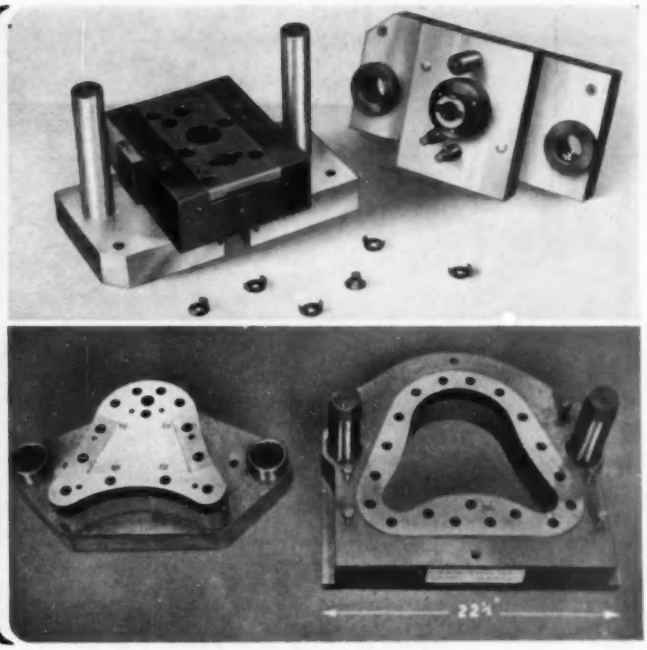

BECAUSE of its high chromium and carbon content, 476 Steel resists wear and is specially suited for exacting punching and forming operations on abrasive materials. It has also considerable toughness, the tool edges standing up to shock applications, such as heavy punching and shearing. The photographs illustrate two contrasting applications. (Top) Three stage press tool for punching and forming clamping washers from brass strip (courtesy, Clarke Chapman & Co. Ltd.). (Bottom) Heavy press tool for blanking hoist bracket in ½ in. thick mild steel (courtesy, Stothert & Pitt Ltd.). 476 is air hardening and machinable in the annealed condition. Applications include blanking dies and punches for sheet brass, copper, zinc, high silicon transformer steels and hard abrasive materials generally ; blanking tools for steel sheet and plate ; blades for flying strip shears and plate shears ; deep drawing dies, cupping dies, forming dies ; sheet metal forming rolls ; circular cutters for strip ; trimmer dies, thread rolling dies ; gauges and other precision tools ; taps, staybolt taps ; brick mould liners ; master hobs for cold hobbing plastic moulds ; cut moulds for plastics.

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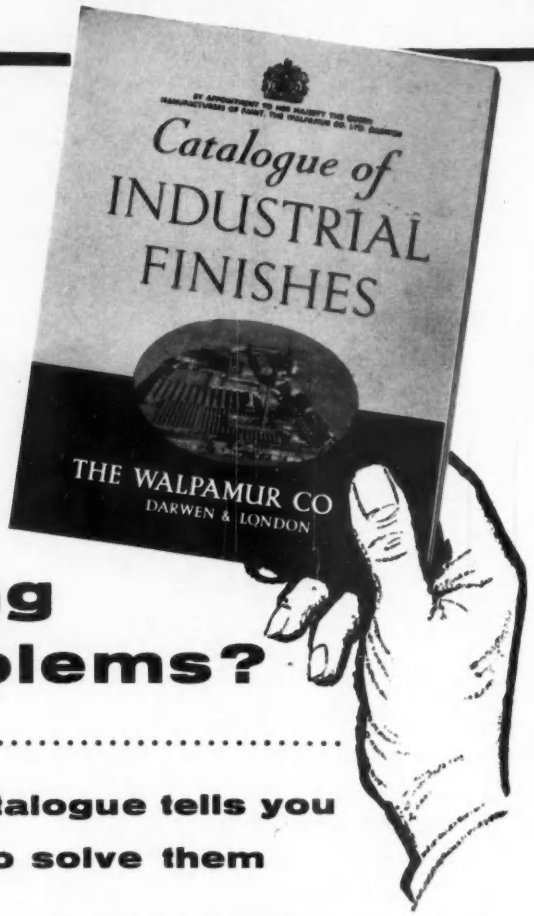

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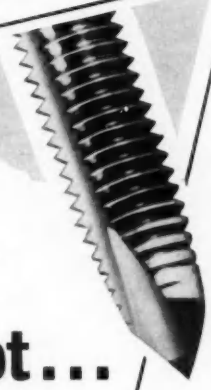

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English Steel Tool Corporation Ltd.,
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Manchester.

9th July, 1956.

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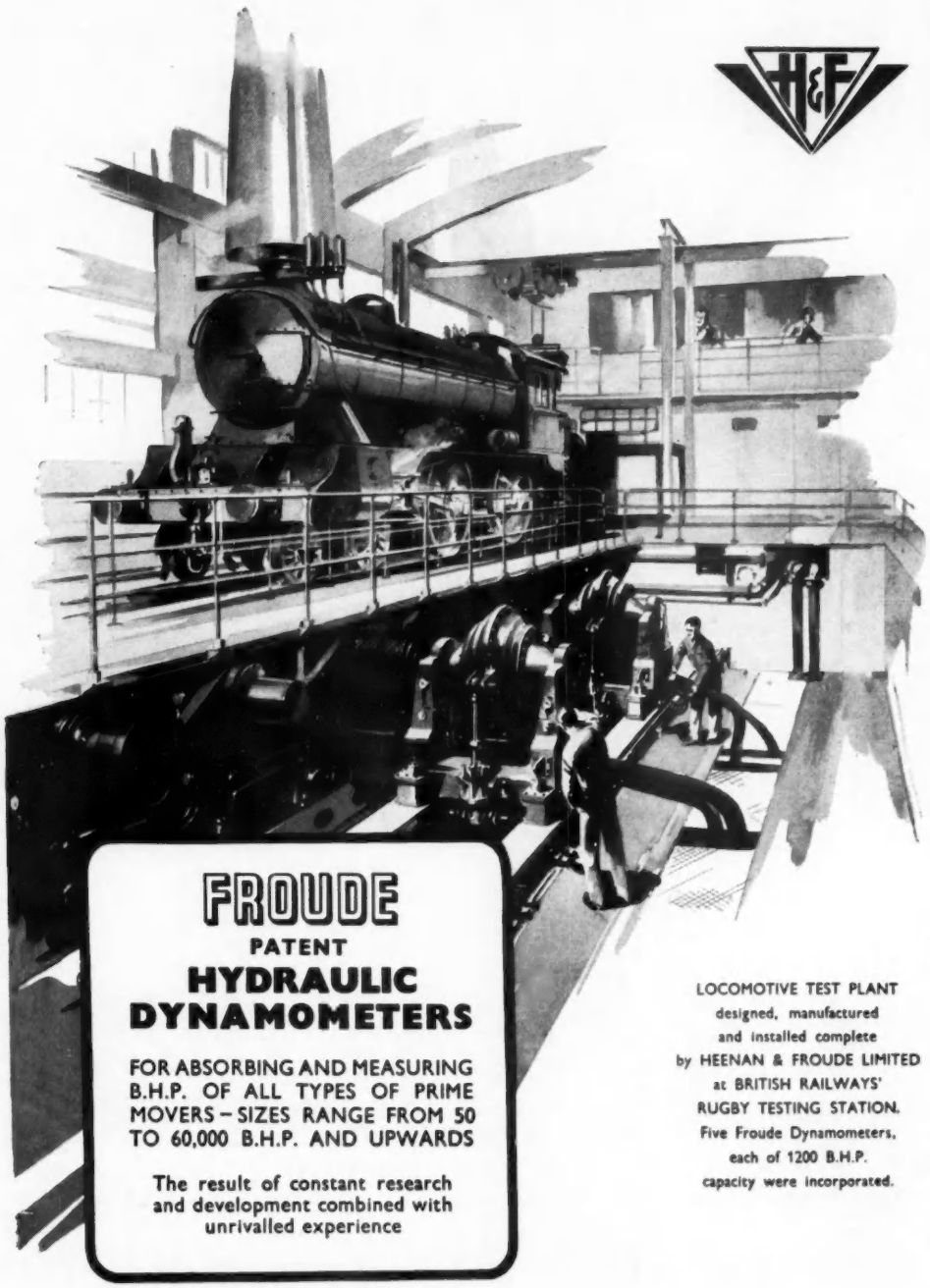

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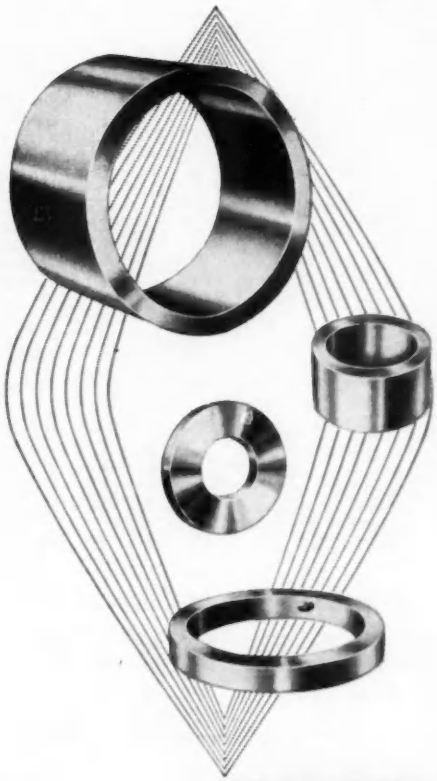
centrifugal force

the governing factor



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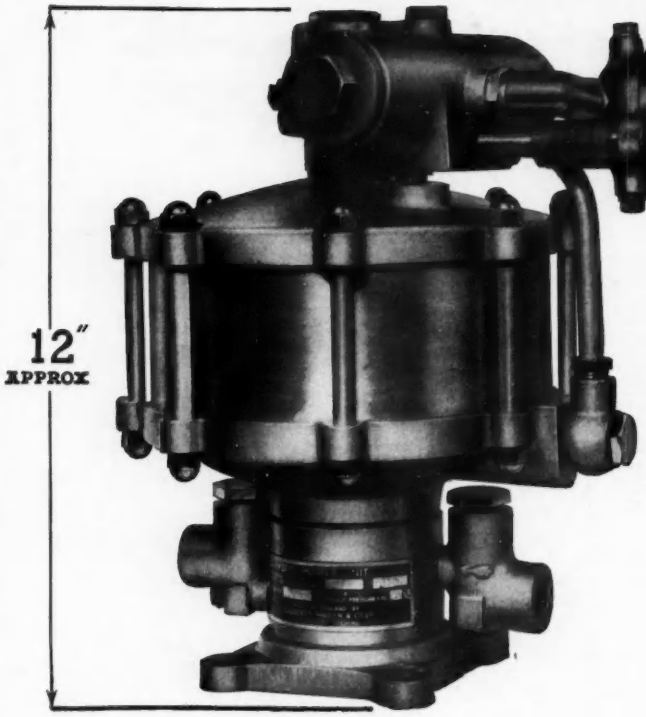

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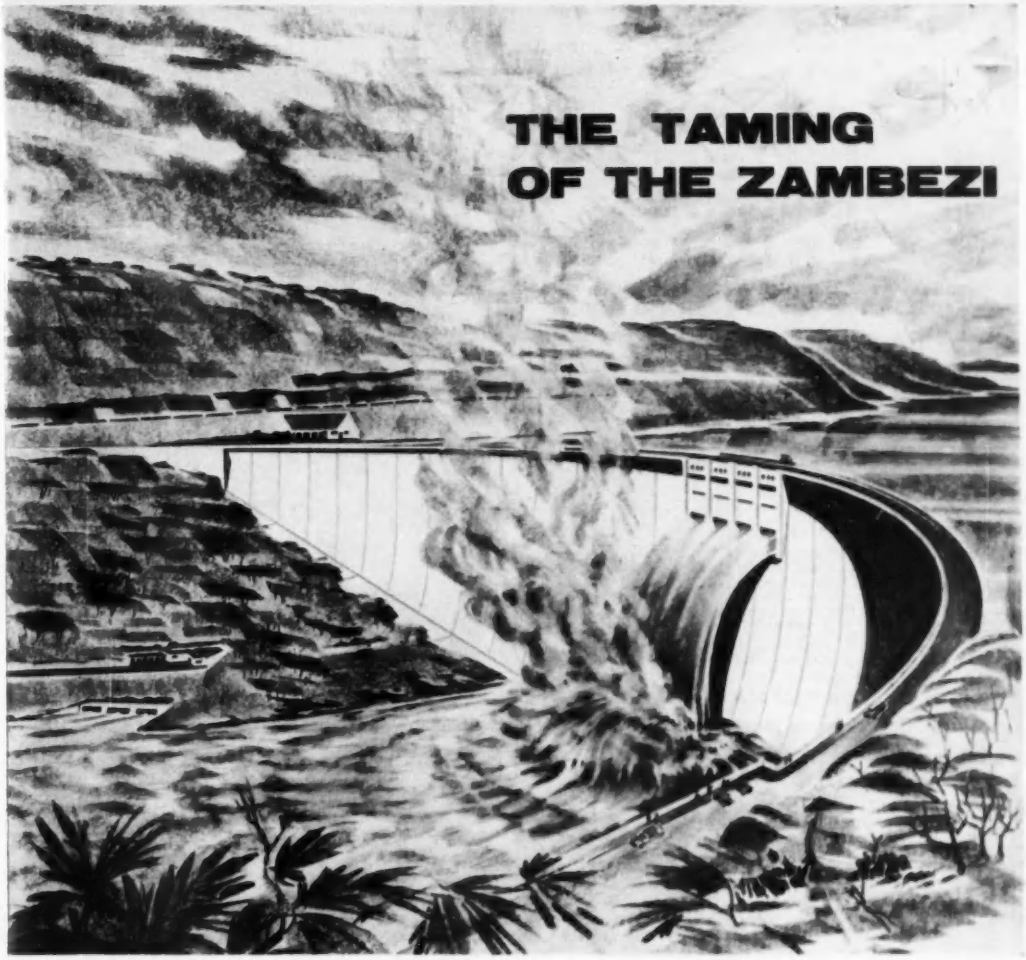

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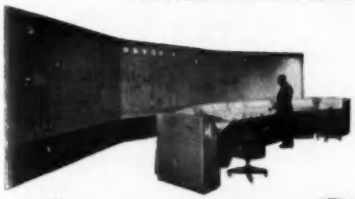

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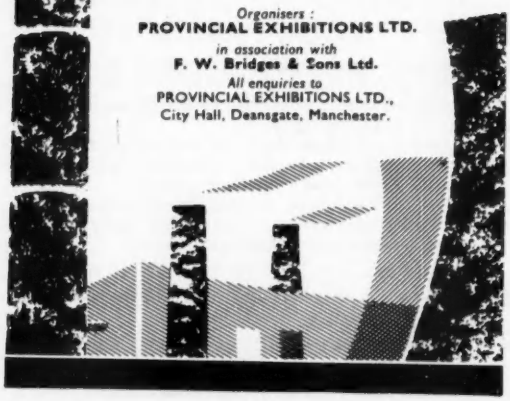

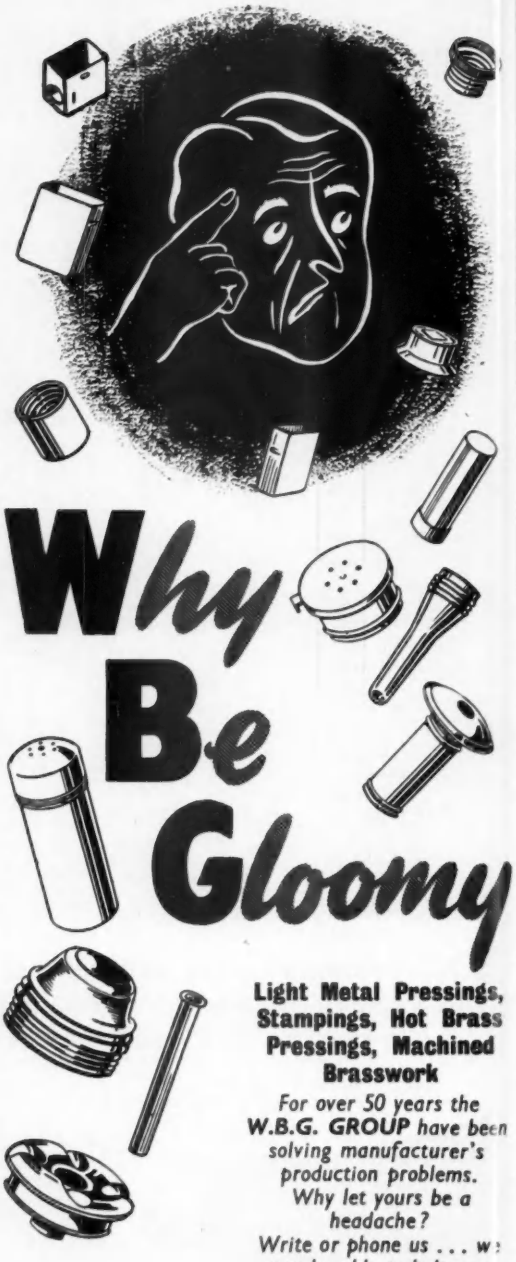

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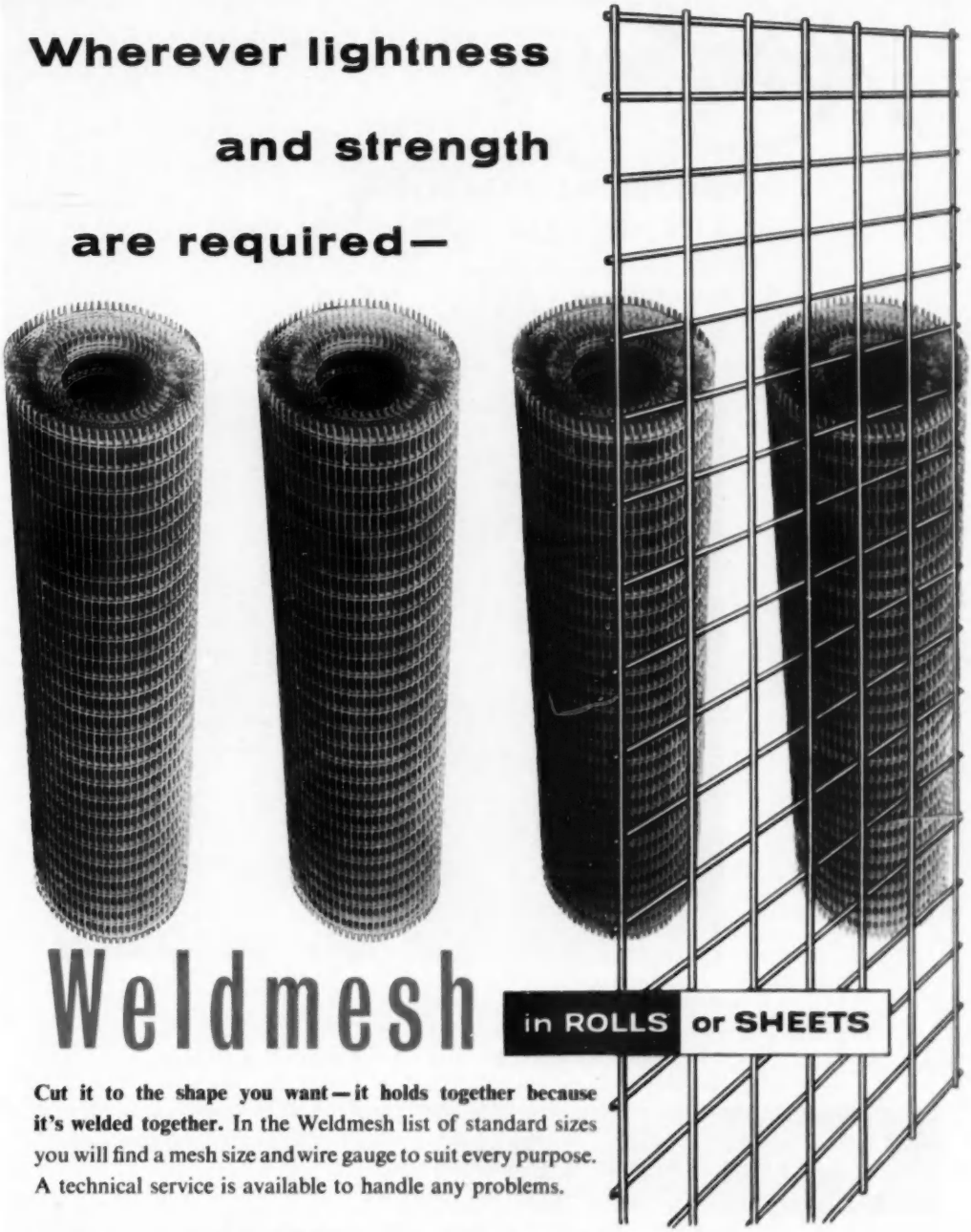

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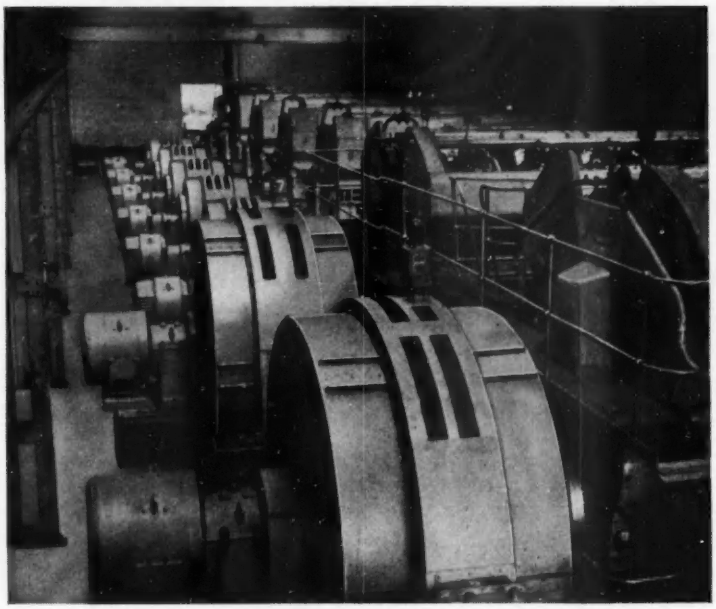

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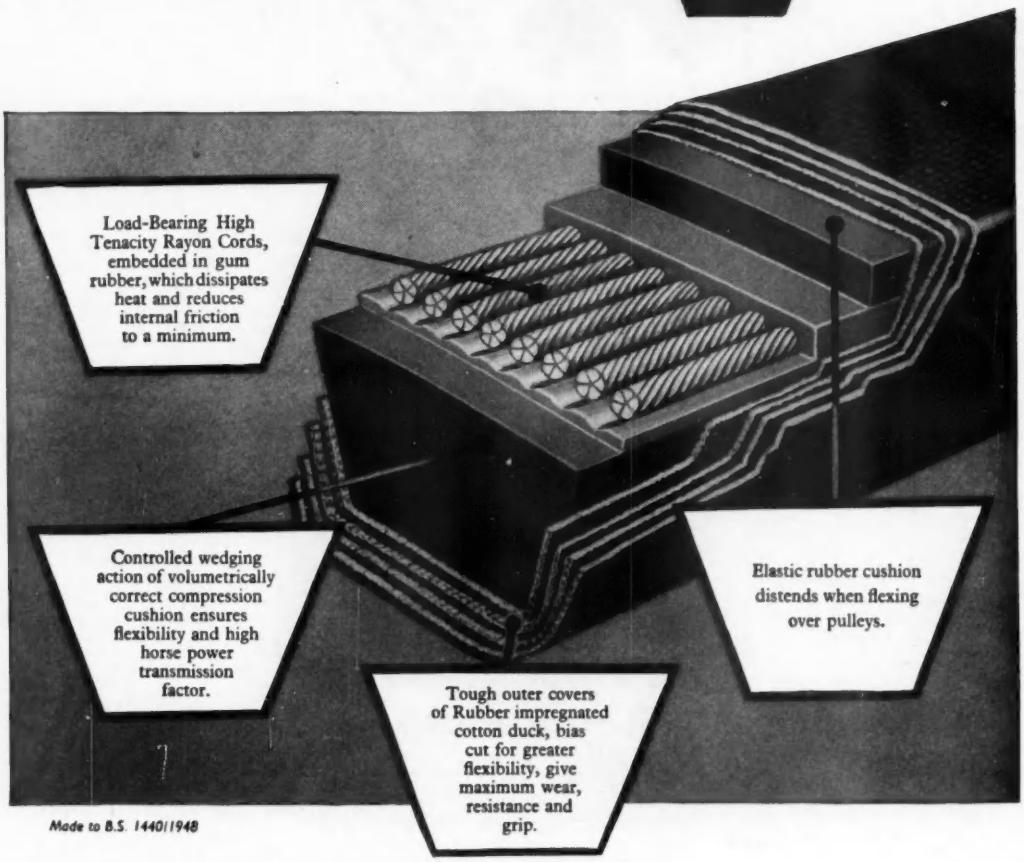
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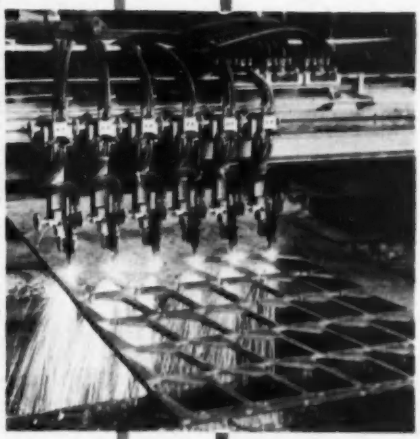

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"Well, you see Johnny, it's because *your* sort of magnet can't be switched 'on and off'!"

"*Huh! I wouldn't like mine to do that!*"

"I know, but then you don't use yours to control water or gas and things."

"*Control water or gas?*
Seems stupid to me—why can't
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"Ah! But using a tap means that you rely on what's called the 'human element'. That's why these valves are fitted to do things automatically —without people being involved."

"*Mr. Stevens told me they make chocolates with them!*"

"That's right, but not exactly to *make* chocolates, to *help* make them. Mushrooms too!"

"*Cor! I like mushrooms.*" *(Throwing away magnet)*
"*Can I have some for tea?*"

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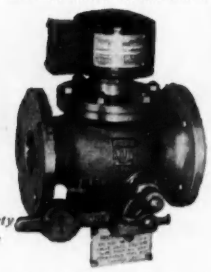

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FOR POWER GENERATION IN

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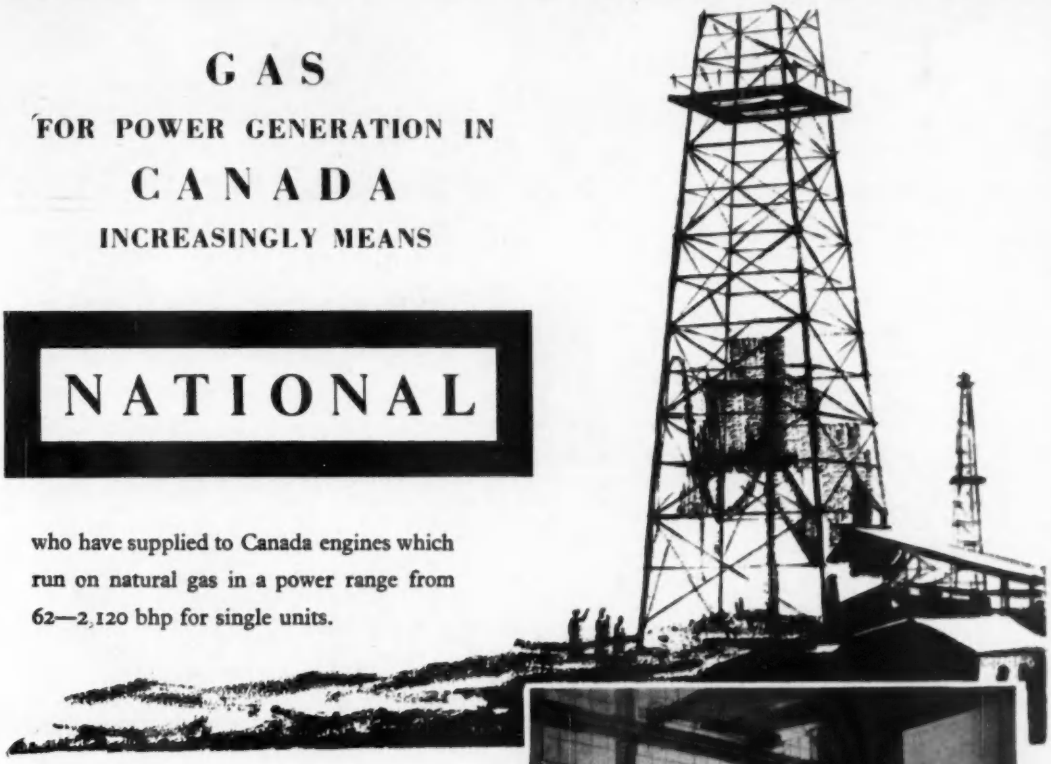

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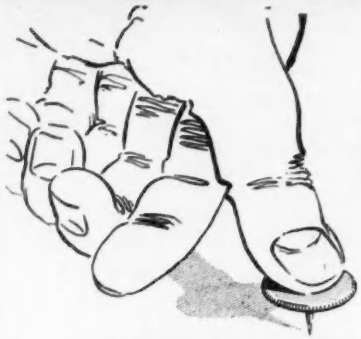
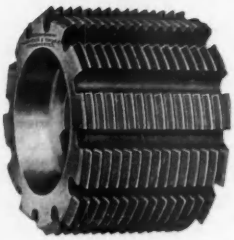


MULTIPLE THREAD CUTTER



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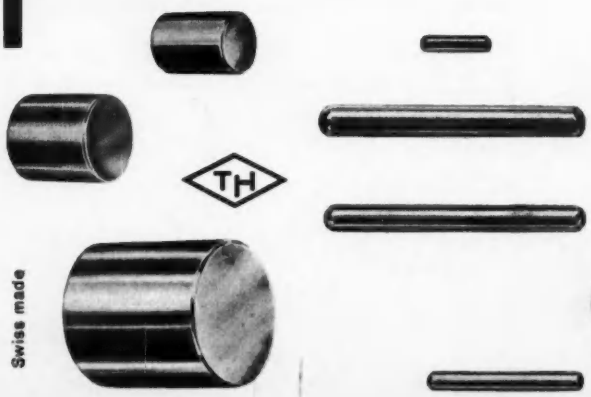

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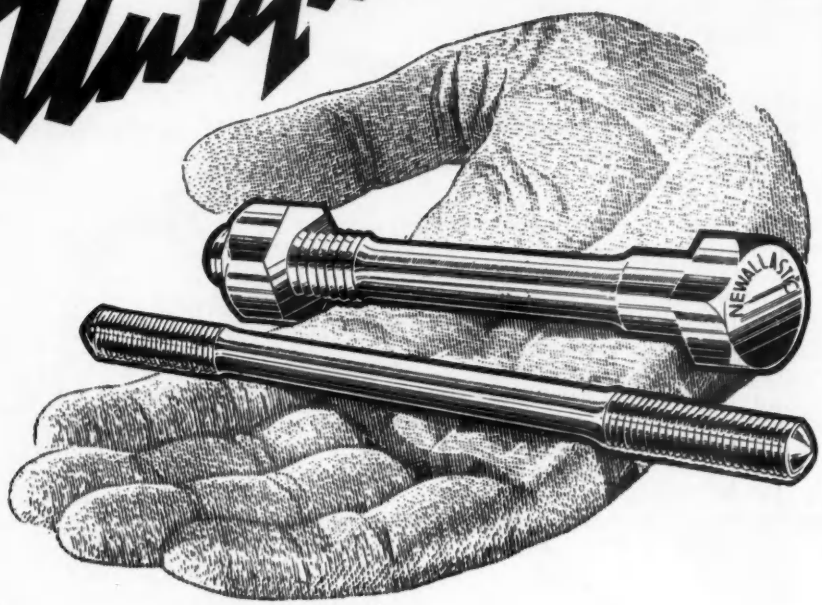

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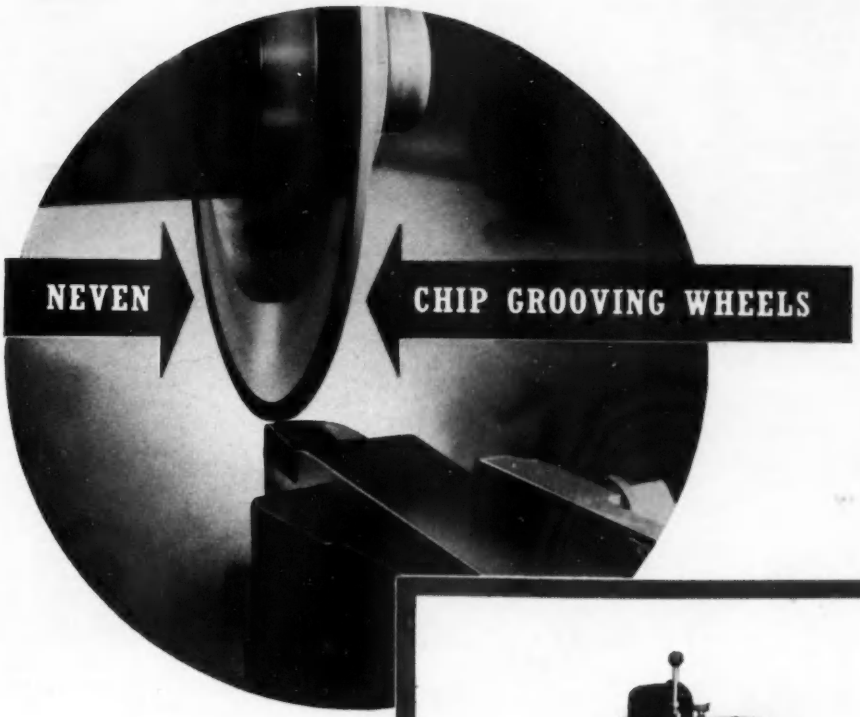

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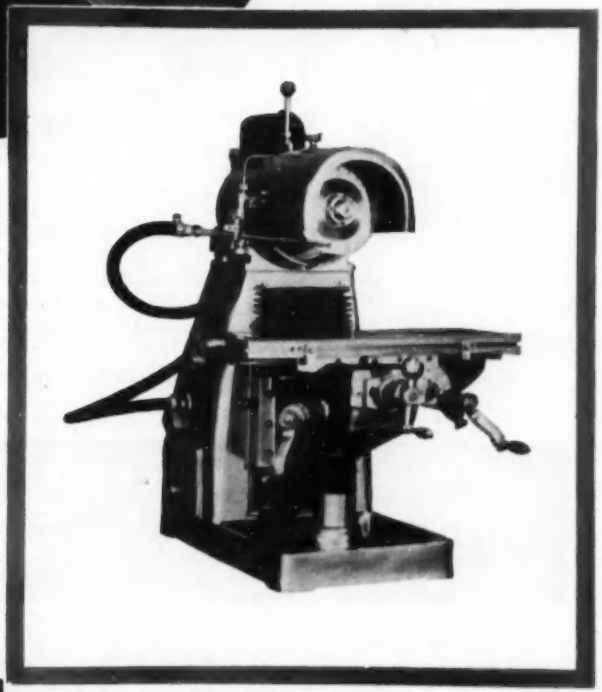

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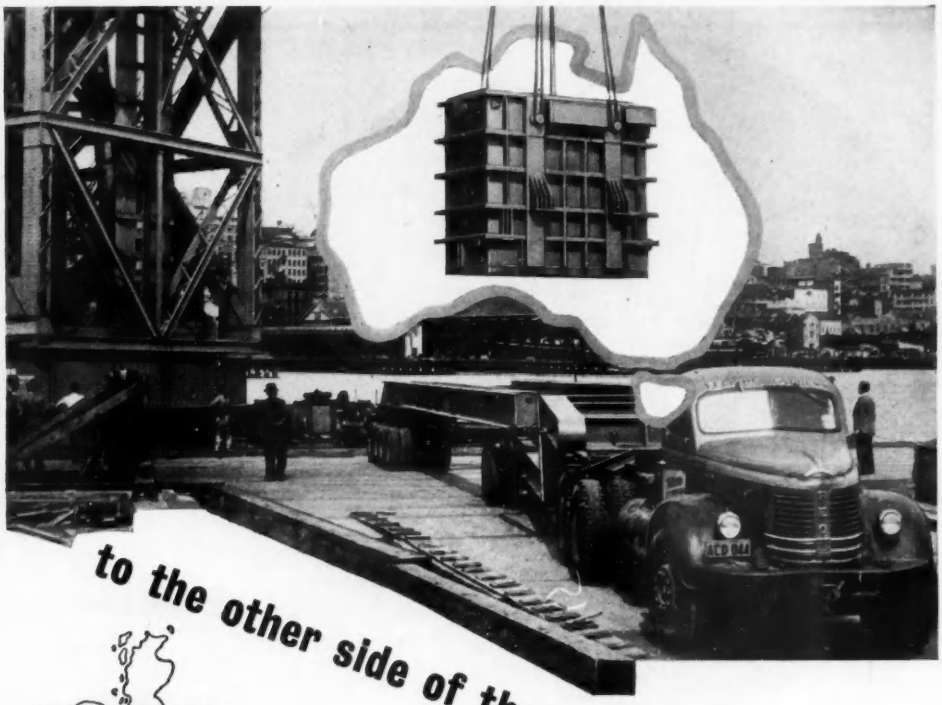

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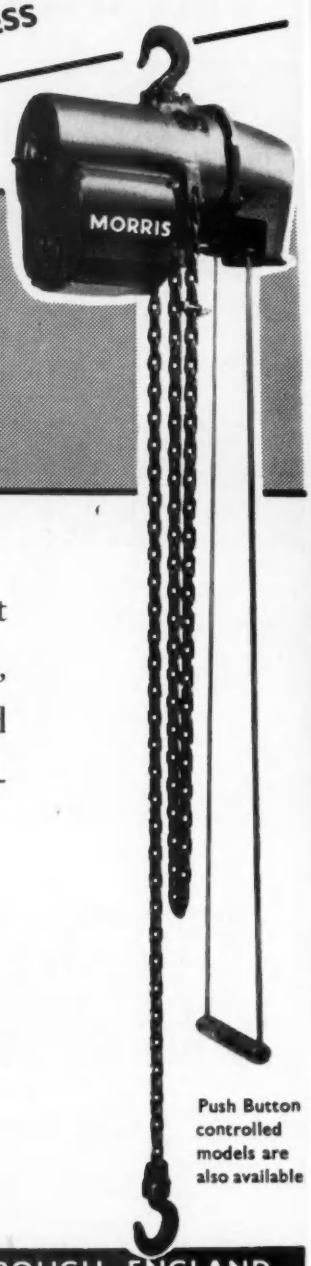

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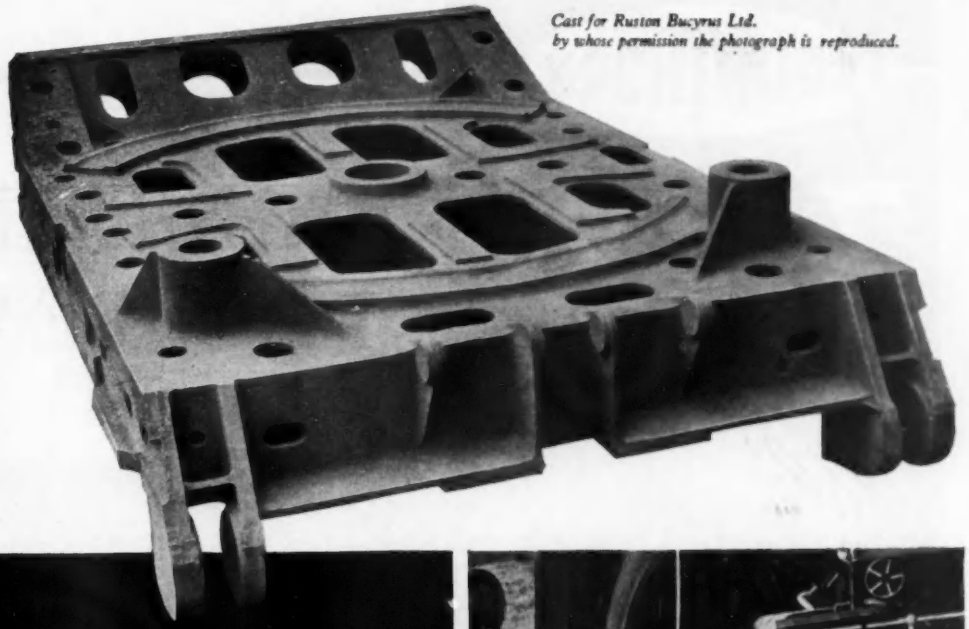

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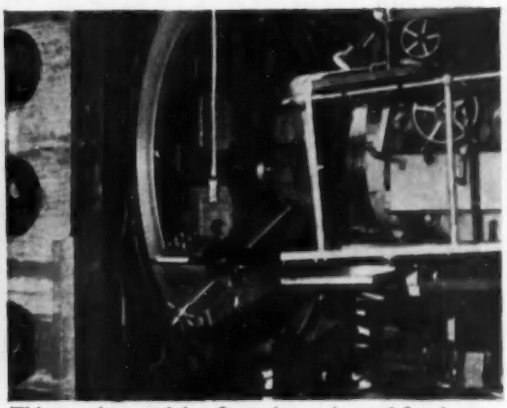
cast and machined for an important part



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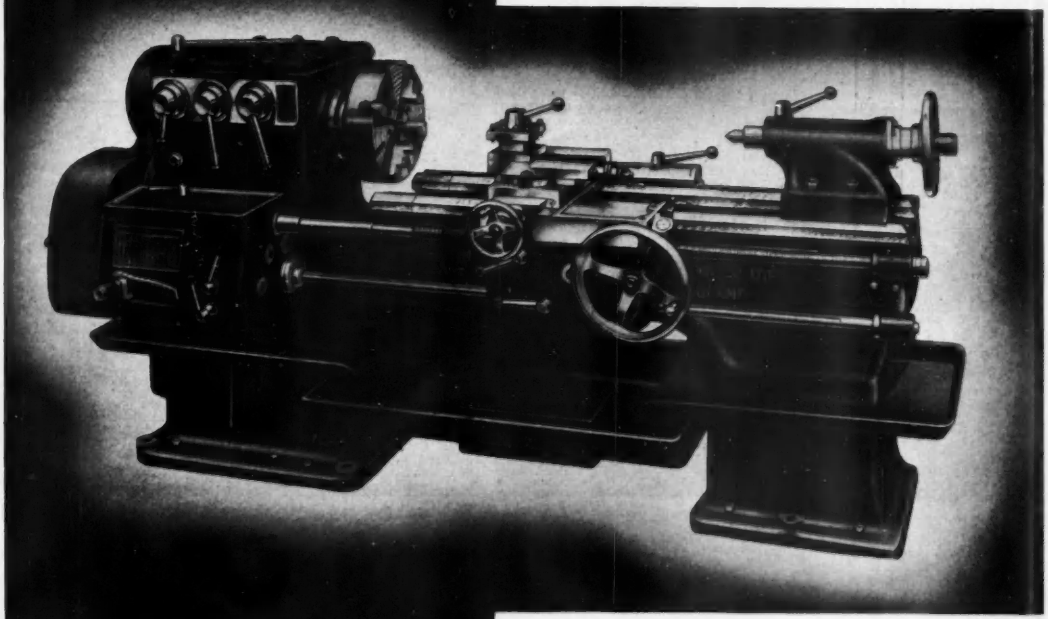

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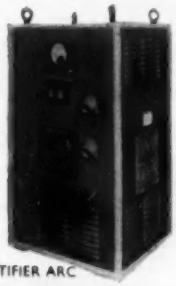

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AC ARC

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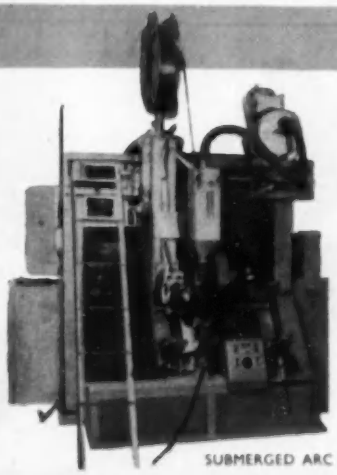

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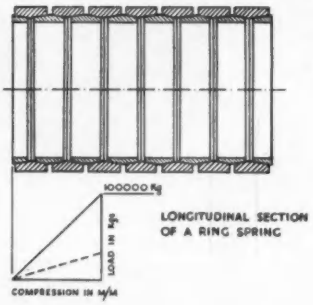

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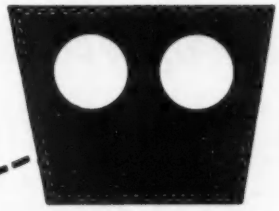

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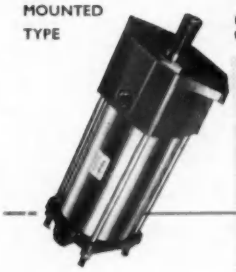

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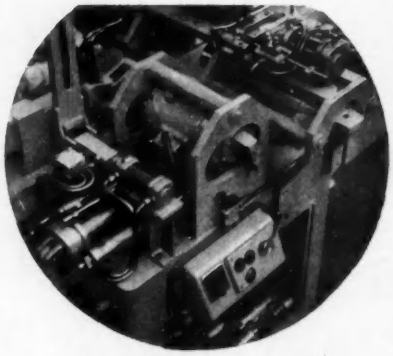

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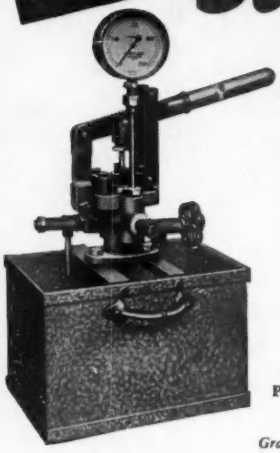

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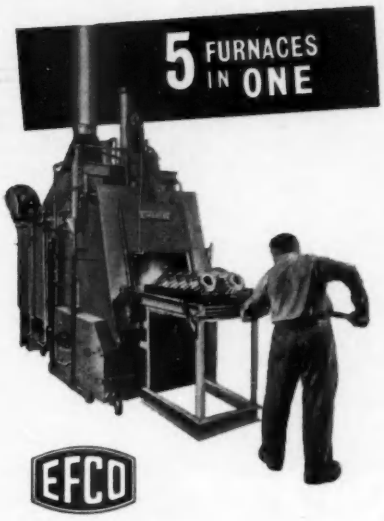

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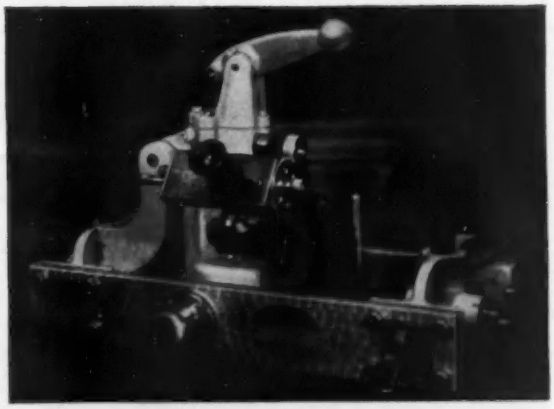

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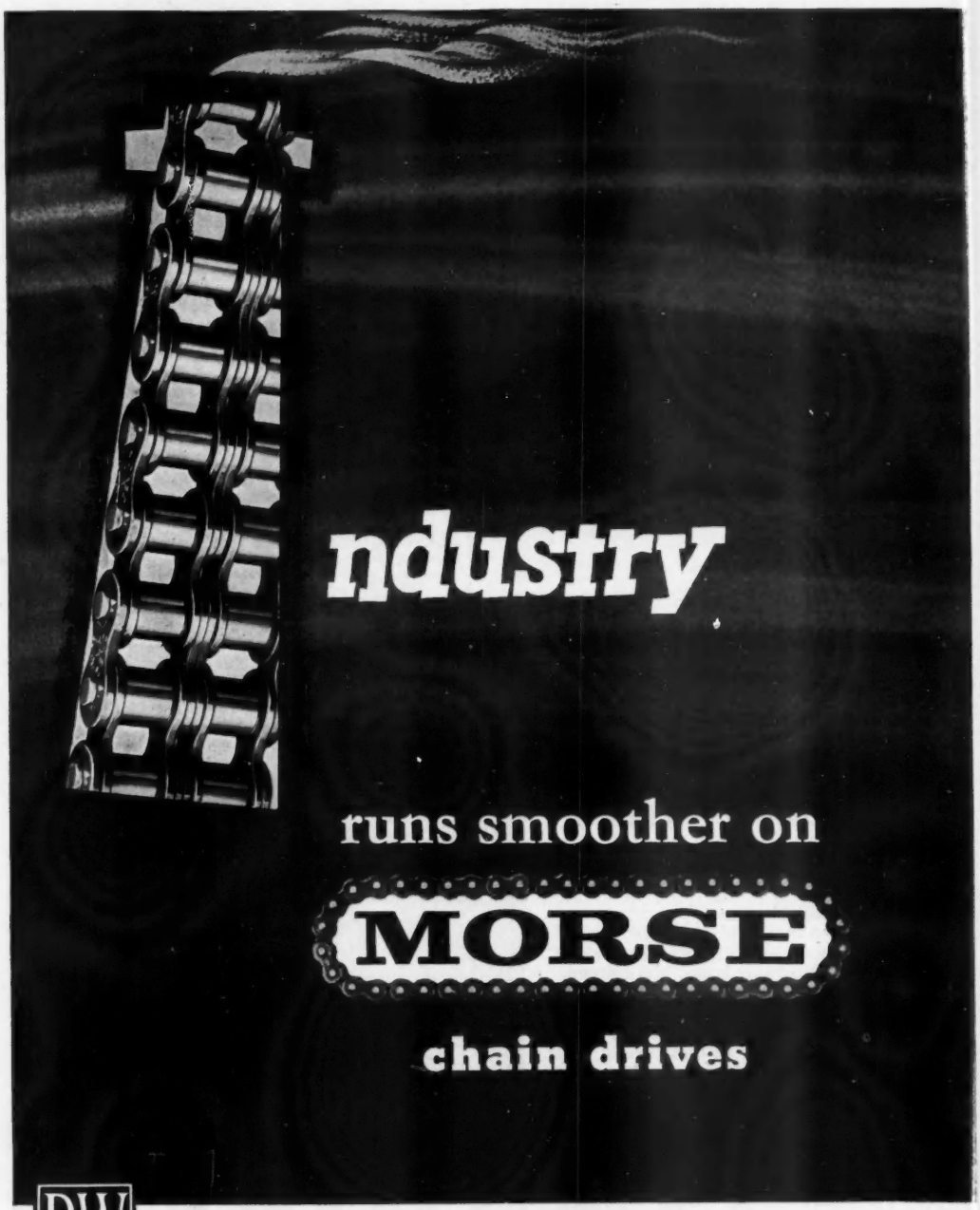

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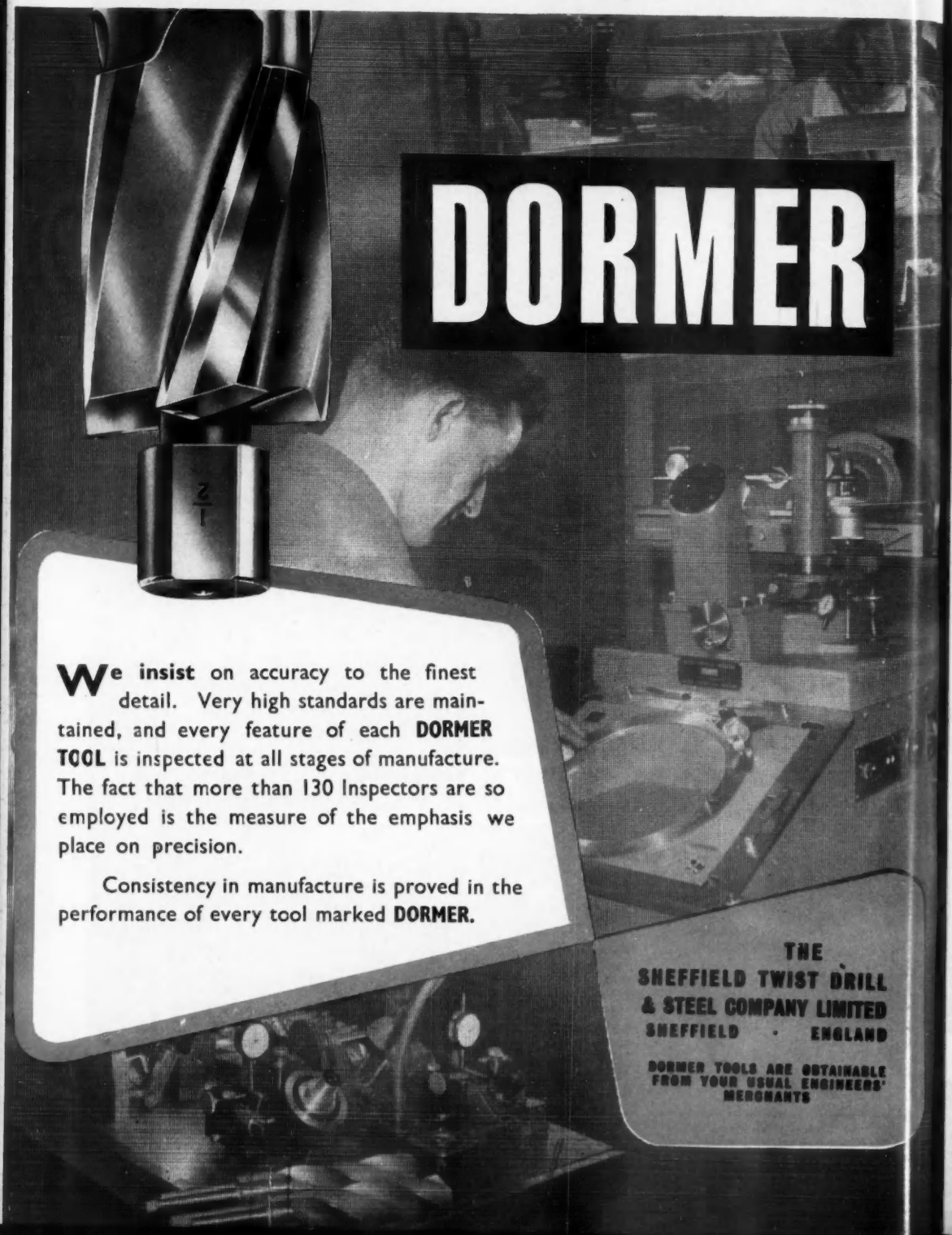

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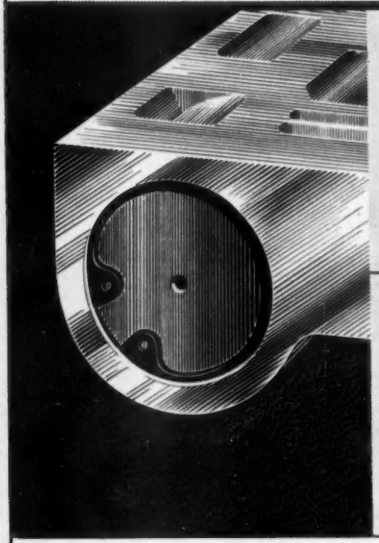

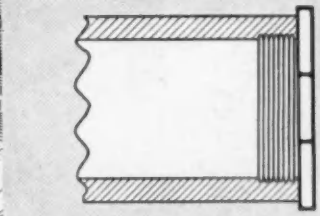

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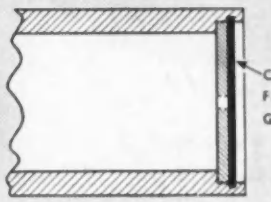
This fluid seal involved internal threading of the tube, which was sealed with an expensive cap-nut. The assembly was laborious and spanners were needed.



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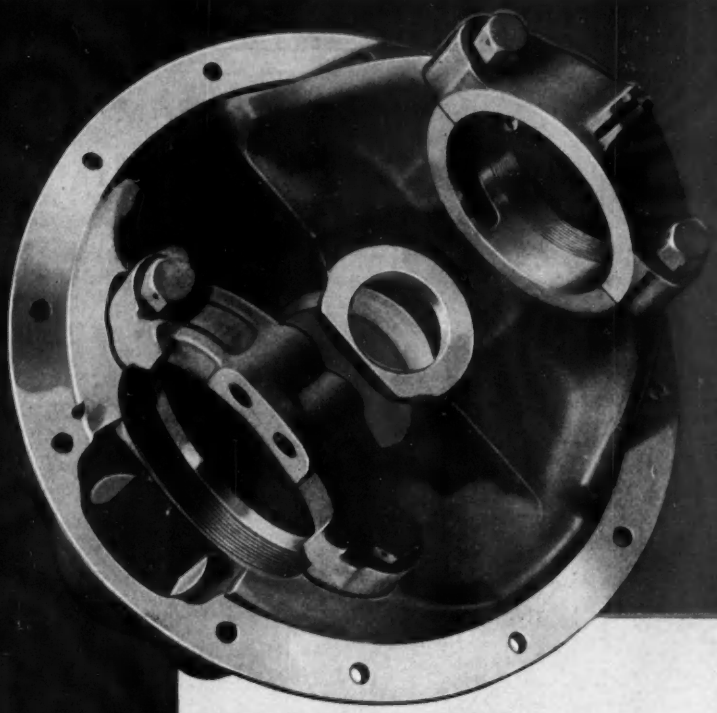

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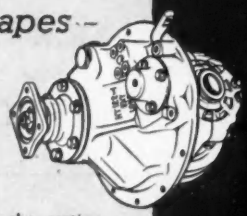

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *ELECTROLYTIC SHAPING OF SEMICONDUCTORS*

In one method of removing material from a conductive or semiconductive material, a jet of liquid electrolyte is directed against the material, and a voltage of suitable polarity is applied between the electrolyte and the material. The disadvantage of this method is, however, that the desired removal of material from the surface of the element takes place very slowly and the depth of the recesses formed by the jet cannot be varied as desired, while the degree of accuracy obtained is insufficient to produce recesses for the reception of the electrode material for semiconductor crystals. According to a recently patented process, these difficulties have now been overcome. Basically, the method comprises the use of a drop of electrolyte placed between an electrode and the surface of the element, the electrode being located at such a distance from the surface of the element that the drop of electrolyte is held between them. The current is then passed through the electrode, the drop of electrolyte, and the element. The size and shape of the electrode should preferably correspond to the profile to be imparted to the surface of the element, and the electrode is continuously moved in the direction of the surface from which material is being removed, thus maintaining a constant distance between electrode and the surface. If a well-defined constant electrode spacing is maintained in this way, the depth and width of the recess or the profile of the space formed can be controlled to within fractions of a micron. Another advantage afforded by constant electrode spacing is that only a very small quantity of electrolyte need be used. Furthermore, if the electrode is made with a fine point, it is possible to produce apertures or recesses of any desired fineness in the element, which may be, for example, a semiconductor mono-crystal. It is also possible to carry out two simultaneous electrolytic operations coaxially from both sides, so as to produce a thin zone of exactly defined thickness at the centre of the semiconductor crystal. Moreover, if desired, several electrodes can be disposed in juxtaposition, enabling a number of recesses to be formed on the same side of the element.

● *PRECISION DELAYED-PULSE GENERATORS*

Delayed-pulse generators, i.e., generators which produce a pulse at a known and selectable time following a trigger signal, provide an excellent tool for measuring and establishing accurate time intervals in the microsecond to millisecond region. A new digital delay generator provides an initial zero reference pulse and two positionable pulses, all of which are accurately known in time with respect to an external trigger pulse. To achieve a precision delay which is time-locked to an external trigger, it was found necessary to develop a special pulsed crystal oscillator with a constant starting phase, in addition to a constant starting amplitude. Special counter circuits capable of multiple presets have also been developed. Basically, the pulsed crystal oscillator is a multi-stage circuit which also has a negative feedback loop controlled by a gate. During the time when no delay is being generated, the gate holds the negative feedback path in operation, thus preventing oscillation. When an external trigger is received at the instrument input, it is amplified and applied as a command pulse to the oscillator gate, which then disables the negative feedback loop and simultaneously applies a voltage step to the network containing the quartz crystal. This network is arranged to act as a bridge, so that the voltage step is suppressed to a large extent at the bridge output, though the crystal itself becomes excited by that component of the step which coincides with its frequency. The arrangement thus provides a phase lock between the voltage step and the start of crystal vibration. Besides being designed to produce output pulses after a selectable number of cycles from its own internal precision oscillator, these generators can alternatively count and operate from external periodic or aperiodic frequencies lying anywhere between 10 c/s and 1 Mc/s.

● *DETECTION OF LEAKS IN GAS-FILLED CABLES*

In detecting leaks in gas-filled high-tension electric cables by means of the halogen gas-leak tracer, difluoro-dichloromethane is normally used as the tracer gas. As this gas liquefies at about 45 psi, under normal working temperatures of the cable, the gas pressure in the cable, which is usually some 225 psi, is first reduced to about 45 psi before introducing the tracer gas. A recent proposal involves the use of trifluoromonochloromethane as the tracer gas, the halo-

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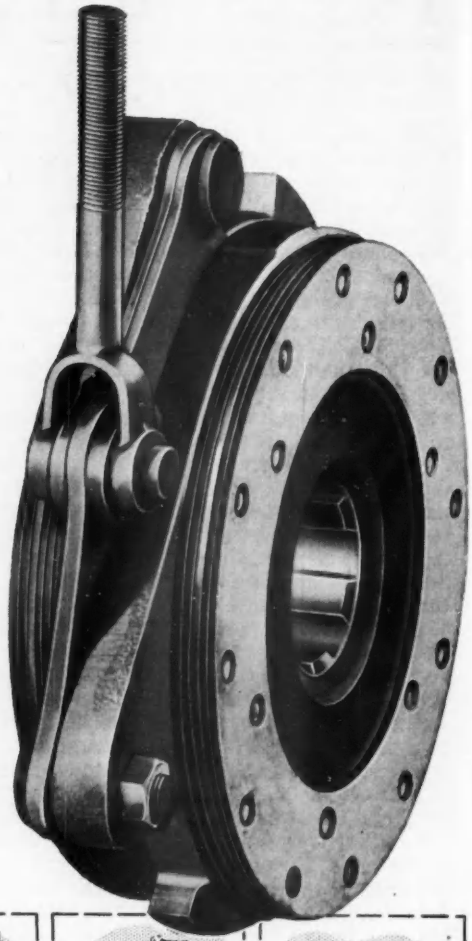

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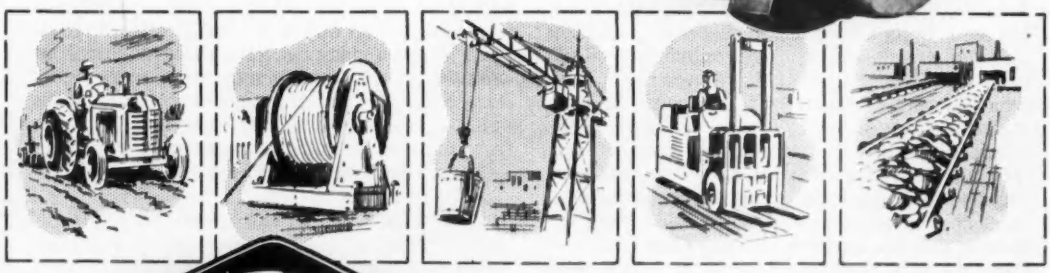

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gen leak tracer being also highly sensitive to this gas, which in its other chemical properties is very similar to difluoro-dichloromethane. Trifluoro-monochloromethane has, however, the advantage that it does not liquefy under normal cable temperatures until above about 300 psi, so that detection of a leak can be carried out under considerably higher gas pressures than have hitherto been possible. It is therefore sufficient to add to the already existing working gas in the cable a quantity of trifluoro-monochloromethane sufficient for leak measurement, which can then be carried out without reduction of the working pressure of the cable. For determining the location of the leak, it is, of course, possible to increase, as desired, the proportion of the tracer gas in the gas mixture in the cable under investigation. The new method has the advantage that it is not necessary to wait until the cable can be withdrawn from operation, and that detection of the leak is carried out more easily, because more gas, as a result of the higher pressure, escapes from the leak in a given time.

● *COBALT-BASE ALLOYS FOR HIGH-TEMPERATURE SERVICE*

It is generally known that an increase in the tungsten content of cobalt-base alloys results in increased high-temperature properties, but, as emphasized in a recent patent specification, it has also been believed that the improvement in such high-temperature properties would necessarily be uniform in character. It is now claimed, however, that improvement in high-temperature properties resulting from the incorporation of increasingly larger amounts of tungsten in cobalt-base alloys is not uniform ; thus, a marked and sudden increase in the improvement occurs when the tungsten content reaches a value of about 18·75%, and this improvement is effective up to about 23·25% tungsten. Higher tungsten percentages do not, however, result in any significant improvement. Tests were conducted on lap-joint test specimens made of stainless steel, with the cobalt-base alloy applied as a fillet on both sides of the lap joint. Precautions were taken to prevent any of the fillet material from flowing into the joint, and the fillets were maintained with uniform dimensions in all the test specimens, which were then heated to a temperature of 1600°F and maintained at this temperature for 20 min, after which they were subjected to a test to determine their ultimate strength at this temperature. In this way it was ensured that not only did each testpiece attain the desired temperature, but also that stresses which might have been produced by the welding operations incidental to the formation of fillets were substantially eliminated. The alloys developed have a carbon content of 1·3 to 2·25%, a chromium content of 26 to 30%, a cobalt content of 44 to 51%, and a tungsten content of 18·75 to 23·25%. The content of silicon is 1·75% maximum, and of iron 3% maximum. It is stated that these alloys are especially resistant to fatigue at high temperatures and that they have been found to be particularly useful in applications for which cobalt-aluminium-tungsten alloys of conventional analysis ranges have proved to be inadequate.

● *TAR-BONDED BASIC REFRACTORIES FOR OXYGEN CONVERTERS*

As oxygen converters employ basic slags, the vessel must be lined with a basic refractory, and for this purpose tar-bonded refractories may be used to particular advantage. In making tar-bonded refractories a fine fraction is ground and blended with a coarse fraction. To achieve adequate densities of about 180 lb/cu ft, the mixture of coarse and fine particles must be carefully proportioned. Ground magnesia is commonly used for the fine fractions of tar-bonded basic refractories, the coarse fractions of which are made from dead-burned dolomite. The amount of tar used to bind the bricks together may vary, depending on such factors as the composition and porosity of the refractory granules, their size, and the intended use of the bricks. Various bricks contain from about 4 to 7% tar, and probably the most important quality of the tar lies in its coking characteristics, which are much more favourable with coal tar than with substances like asphalt. When coal-tar pitch is heated, a large proportion of it decomposes, leaving a carbon residue which acts as an intermediate temperature bond for the bricks, and which produces a refractory with good spall resistance. The carbon bond is resistant to slag attack, but will oxidize ; on the other hand, when an asphalt binder is heated, most of it volatilizes without decomposing, and little or no bond is left. At room temperature, tar-bonded bricks are strong and tough and may be handled with little likelihood of breakage, but strength decreases as the temperature rises to the point at which the tar softens. At temperatures of about 1500°F, when fired under reducing conditions, the tar decomposes and cokes, forming a carbon bond which markedly increases the compressive strength of the bricks. As the temperature of a steel-making furnace is approached, ceramic bonds begin to form.

● *NEW HYDROTHERMAL TECHNIQUE FOR GROWING SYNTHETIC SAPPHIRES*

As a result of a new hydrothermal technique for growing cultured or synthetic sapphire crystals, large sapphires, up to ¾ in. square and ¼ in. thick, have been produced, and the crystals are essentially strain-free, thereby making them

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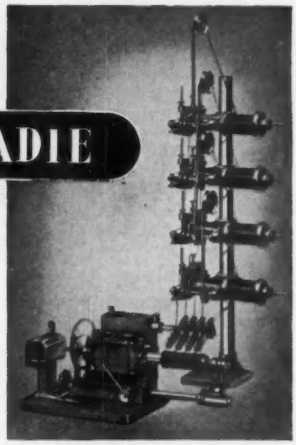

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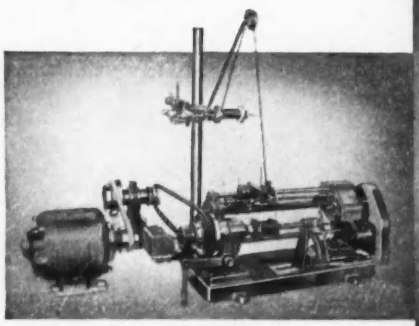

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superior, for optical purposes, to crystals grown by other processes. Aluminium oxide, which is normally considered insoluble in water, can be dissolved and recrystallized from aqueous solutions if sufficiently high temperatures and pressures are used. This is the basis of the hydrothermal process, which employs high-temperature, high-pressure conditions to increase the solubility of aluminium oxide to a point where it can be crystallized on a seed. For growing sapphires, pressures of the order of 20,000 to 50,000 psi and temperatures of 395°C and higher are used. The rate of growth varies with conditions, but typical values are from 0·002 to 0·010 in. per day, though even greater rates of growth appear feasible. If the nutrient solution is doped with small amounts of a chromate, the resulting crystal is a synthetic ruby, whose colour is a function of the amount of chromate added. This synthetic ruby has possible applications as a solid-state maser. Different reagents have been tried in the growth process, including aluminium hydroxide and several forms of aluminium oxide. When aluminium hydroxide is used under the proper conditions of temperature and pressure, it is all converted after a few days to tiny corundum crystals, instead of being deposited on the major seed crystal. This technique may prove of value as a means of making corundum for abrasive purposes.

● *CLOSE-TOLERANCE TEMPERATURE MEASUREMENTS*

High accuracy and reliability in the electronic systems of missiles and in computing equipment frequently demand the employment of means capable of precise temperature measurement. A recent report points out that experiments with electromechanical components, such as liquid-cooled gyroscopes and accelerometers, have led to the development of techniques for dynamic temperature measurements with relative accuracies of 0·01°F or better, and absolute accuracies of 0·1°F. The choice of sensing elements depends on the range of temperatures and linearity requirements. For most laboratory work, platinum or pure nickel wire-resistance elements in a three-wire Wien-bridge circuit are quite satisfactory. These units consist of a zigzag of wire embedded in plastic or of several turns of wire wound around a thin card provided with a coating to eliminate moisture absorption, and held suspended in an air stream, cemented to metal surfaces, or in a wire-cage probe for liquid sensing. The use of thermistors as sensing elements is reported to be under investigation, but it is stated that the advantage of their higher sensitivity is partially offset by reduced linearity. In addition, insufficient knowledge of their stability and drift for repeatable measurements of 0·01°F or better at present prevents their unqualified recommendation. Obviously, the current passing through any sensing element must be sufficiently small to prevent errors due to self-heating. If the element is in good thermal contact with the material whose temperature is to be measured, a current level of from 1 to 3 mA can usually be tolerated. Direct-current bridges are recommended, since they may be nulled to within a few microvolts without phase shift or the quadrature current correction required in alternating-current bridges.

● *ULTRA-SENSITIVE ELECTRONIC ANALYSER*

Stated to be at least 100,000 times as sensitive as other types and to be capable of obtaining accurately and simply qualitative and quantitative analyses of complex mixtures, an electronic analyser has recently been developed in England and may well constitute an enormous advance in the technique of gas/liquid chromatography. It is claimed that the instrument is cheaper and simpler to use than other analytical methods. Thus, conventional systems of analysis, using thermal techniques, depend on extremely accurate control of pressure, flow, and temperature of both the column and the detector for ensuring stability and reproducibility. With the new analyser, however, the effects of these variables are so small that the degree of control is set solely by the column requirements. The instrument consists basically of a column surrounded by a heater, in the end of which is located the detector cell. The outlet from the cell is connected to a soap-bubble manometer for rapidly and accurately checking flow rate. An amplifier/power unit supplies a high voltage to the detector cell and also amplifies changes in current produced by the passage of components through the cell, providing an output to a conventional recorder. Controls are provided for altering the voltage applied to the cell and for adjusting overall sensitivity, the range of which is about 1 part of component in from 2×10^3 to 2×10^6 parts of carrier gas (argon) for full-scale deflection of the recorder, the limit of detection being 1 part of component in 2×10^8 parts of carrier gas. Minute samples (0·025 to 0·1 microlitre) are used, and their insertion by means of a micropipette is extremely simple.

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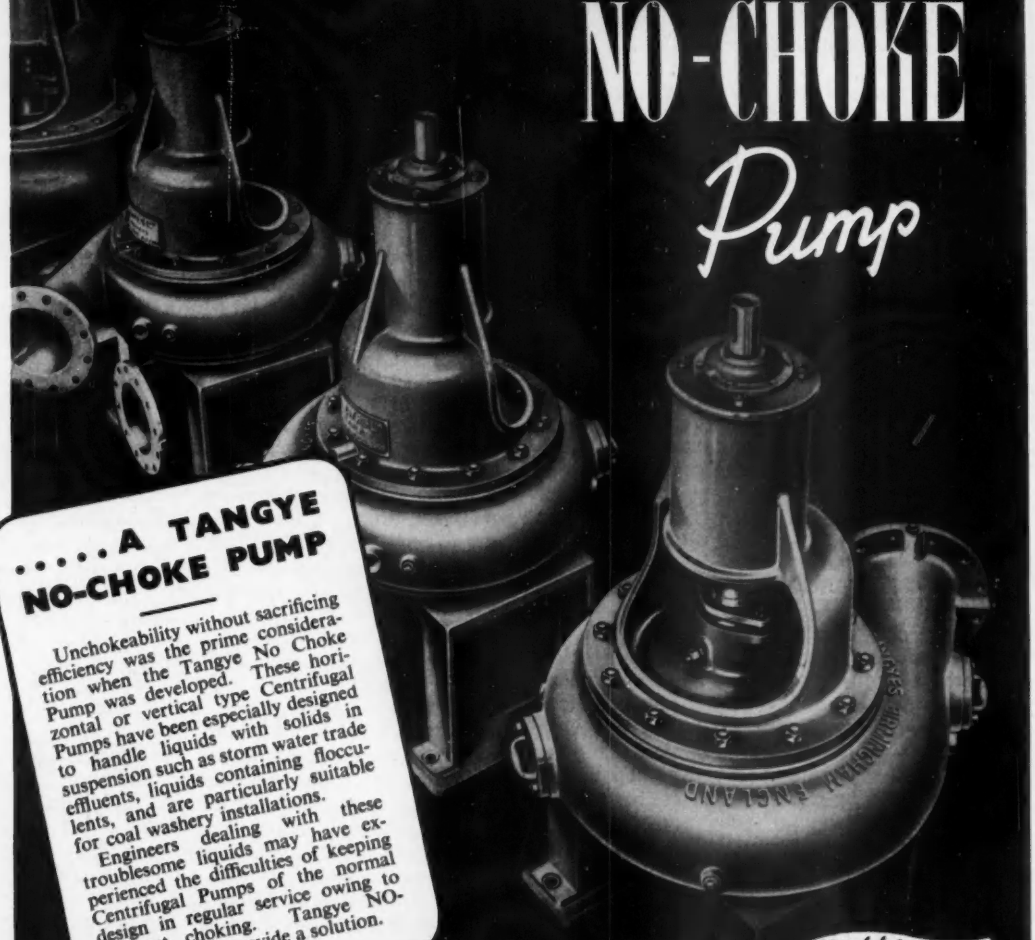

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effects is the so-called freezing method, which requires that the model be subjected to a heating cycle for an extended period of time while loaded. When the heating cycle is completed and the model has been returned to room temperature, the loading is removed and the fringes are found locked in the model. Slices are then cut from the model and observed, the fringe pattern remaining undisturbed if the machining operations are performed carefully. A recent report describes a new method which does not require any heating of the model, since it employs a plastic which cures at room temperature. In this method the transparent model is cast from a modified epoxy resin with an embedded rubber-thread grid. The model is permitted to cure partially before it is loaded, and is then held under load while the plastic continues to cure. After removal of the load, an isochromatic fringe pattern remains which is proportional to the elastic distribution of the maximum shearing stresses. In addition, the permanently distorted grid exhibits deformations which are proportional to the elastic distribution of strains. The new method appears to be well suited for application to the solution of gravitational problems, and also of problems in which a change in temperature alters the boundary conditions. As the report points out, the new material has a lower Poisson ratio than most commonly used three-dimensional photoelasticity materials. It may therefore be possible, by means of grid analysis, to solve a three-dimensional problem without having to resort to numerical integration.

● *SOLID-STATE PHOTOCELLS, USING RADIO-ISOTOPES*

A drawback encountered in conventional photo-electric systems is that the light beams are easily obscured by haze and that lamps requiring a power supply must be used. To overcome these shortcomings a photo-electric system has been developed which uses a radio-isotope source to furnish high-energy radiation in conjunction with a solid-state photocell to detect the radiation. The beam formed cannot be obscured by hazy atmospheres, while components are unaffected by temperature and shock and do not require a power supply. As a source of radiation, a 10-millicurie strontium-90 source is used. The principle usually employed to detect the radiation is to measure the total ionization produced by the radiation absorbed in a volume of material, the ions being collected and averaged into a direct current representing the average ionization rate. In the new system the change in resistance caused by the ionization in an appropriate solid (e.g., cadmium sulphide) is used to detect the high-energy beam. Several types of commercially available cadmium sulphide photocells are sensitive not only to visible light but also to atomic radiation. The particular cadmium sulphide cell used in this instance is of cylindrical shape and is approximately $\frac{1}{2}$ in. in length and $\frac{1}{4}$ in. in diameter, the sensing area being less than $\frac{1}{16}$ sq in. The solid-state photo-electric system consists of the radio-isotope source, the cadmium sulphide detector, and a bistable transistor amplifier. When a shutter, which is made of $\frac{1}{32}$-in. aluminium and which simulates the physical interruption of the beam, is inserted between the source and the detector, the beam is interrupted, and the resistance of the photocell increases. The distance between source and detector must be less than 2 in. to ensure consistent detection.

● *IMPROVED FUSED SALT BATH*

Fused salt baths of widely different compositions are employed for the heat treatment of steels. After treatment, the steel articles will be carburized by the mixture of the fused salts, the depth of carbon penetration depending on the precise conditions under which the treatment is carried out. The particular bath composition to be employed will to a large extent depend on the degree and depth of carburization required in the treated product. If it is required that the carburized casing be relatively small, e.g., up to about 0·025 in., then it is usual to employ fused salt mixtures of the cyanides and carbonates with a halide or mixture of halides of the alkali metals. A recent patent proposes for the heat treatment of steels and alloy steels an improved fused salt bath which consists essentially of more than 50% by weight of an alkali halide or mixture of alkali-metal halides, and a lesser proportion of an alkali-metal cyanide, together with 0·25 to 5% by weight of a regenerator comprising titanium or a mixture of titanium with silicon and/or silica. The cyanide content of the bath must be less than that of the alkali-metal halide, an amount of up to 15% being recommended, with preferably from 1 to 10% by weight of alkali-metal cyanide. In addition, it is considered desirable to include in the alkali-metal halides a quantity of sodium fluoride amounting to less then 10% by weight of the weight of the bath. The new bath is claimed to possess a number of advantages. Thus, for example, it confers on the articles under treatment a depth of carburization which is superior to that obtained with alkali-metal salt baths comprising cyanides and carbonates and possibly also alkali-metal halides. Also, the cyanide usage of the new bath is claimed to be less than that of carbonate-containing baths. Furthermore, as distinct from baths containing alkaline-earth chlorides and alkali-metal cyanides, the salts adhering to the steel articles treated in the new type of bath can readily be washed off with water.

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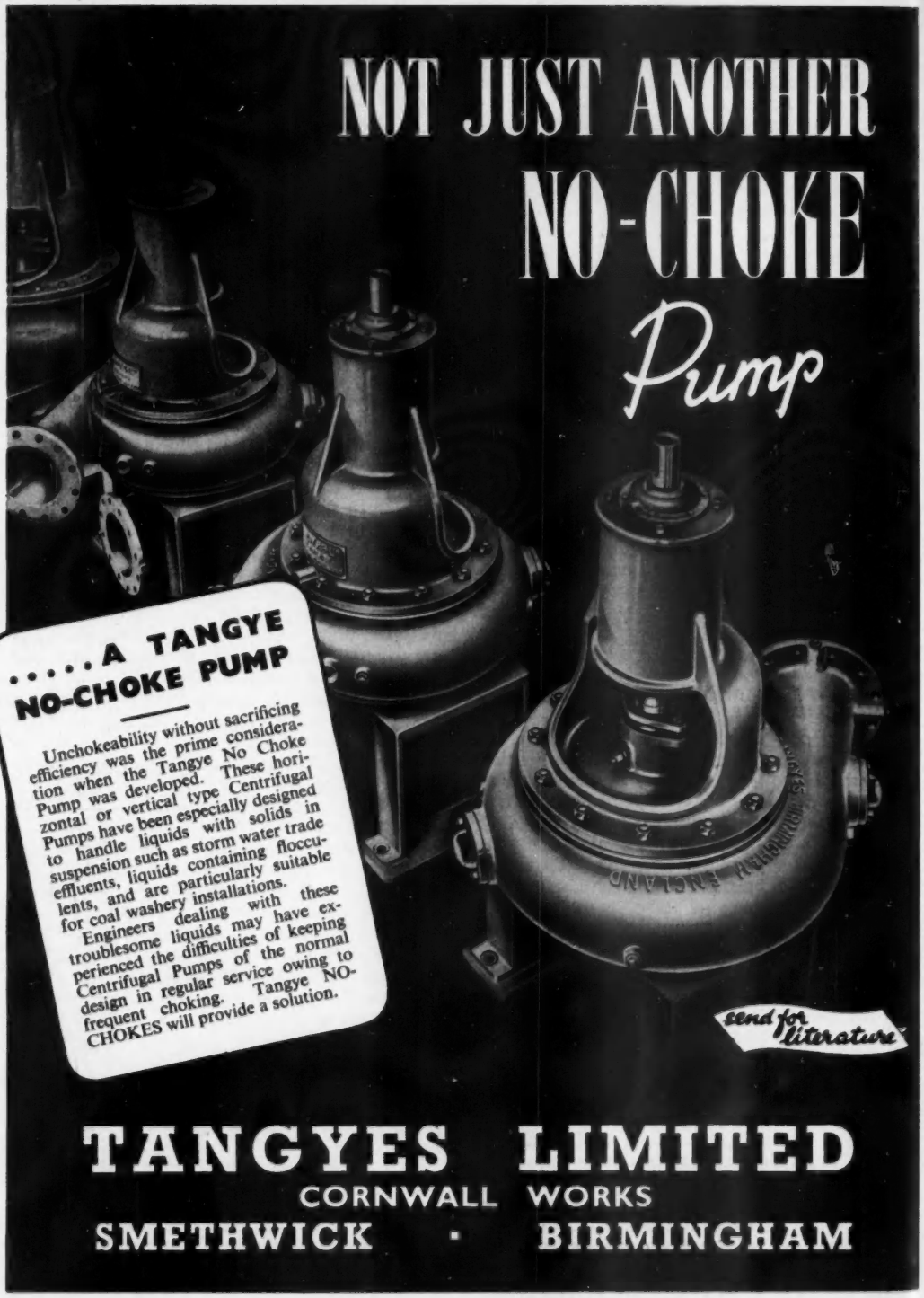

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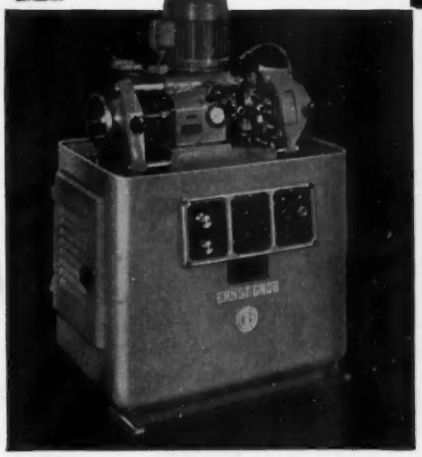

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THE ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

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A Thermionic Energy Converter using Caesium Vapour

By K. G. HERNQVIST, M. KANEFSKY, and F. H. NORMAN. (From *RCA Review, U.S.A.*, Vol. 19, No. 2, June 1958, pp. 244–258, 11 illustrations.)

IT is well known that direct conversion of heat to electricity can be achieved by means of a thermionic diode. Thermal energy supplied to heat the cathode is directly converted into electrical energy, which may be utilized in the circuit connected between the anode and the cathode. For high conversion efficiency in such a device, it is necessary to satisfy two conditions, i.e., (1) the difference between the work function of the cathode and the work function of the anode must be high, in order to take advantage of the contact difference of potential, and (2) the space-charge effects in the inter-electrode space must be overcome. This paper describes a converter tube in which these two conditions are met by using caesium vapour in the tube.

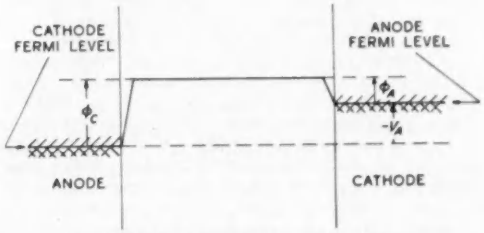

Fig. 1. **Potential-energy diagram for electrons.**

The operation of the thermionic energy converter can most easily be understood by reference to the potential-energy diagram for electrons shown in Fig. 1, in which Φ_C is the work function of the cathode, Φ_A is the work function of the anode, and V_A is the anode voltage. When the external circuit between the cathode and anode is open and there is no net charge between the cathode and anode, there is no field between cathode and anode, and the potential is constant, as shown. By supplying heat to the cathode, some electrons are raised on a potential-energy scale from the Fermi level of the cathode to the top of the potential barrier at the cathode surface. Some of these electrons are emitted from the cathode surface and flow to the anode, provided that space-charge effects in the inter-electrode space can be overcome. When captured by the anode, the electrons fall down on a potential-energy scale by an amount equal to the work function of the anode, i.e., Φ_A volts. This energy appears as heat in the anode. The remaining potential energy of the electrons, when they have reached the Fermi level of the anode, is the contact difference of potential ($\Phi_C - \Phi_A$). This energy is delivered directly as electrical energy to the circuit connected between the anode and the cathode.

Electrically, the converter acts as a constant-current generator capable of a maximum output voltage equal to $\Phi_C - \Phi_A$. A theoretical volt-ampere characteristic is shown in Fig. 2, in which V_A is the anode voltage and I_A the anode current. I_C is the saturated cathode emission current, and O is the point of maximum efficiency.

METHODS OF SPACE-CHARGE REDUCTION

Space-charge cancellation in the inter-electrode space is necessary, if high conversion efficiency is to be achieved, and several methods of reducing space-charge effects have been suggested or tried. Of these, the most straightforward method is that of reducing the cathode-to-anode spacing, but this principle has been shown to be impracticable, because spacings as low as 0·01 mm are needed for reasonable efficiencies.

A second method is that of increasing the particle velocity in the inter-electrode space, and is based on the principle of magnetron operation under cut-off conditions. With this method, a high voltage is applied to the accelerating electrode, but the electrons are forced to move to the anode by a perpendicular magnetic field. However, at high emission-current densities, impracticably high voltages and magnetic fields may be required.

In a class by themselves are methods using space-charge neutralization by positive ions in the inter-electrode space. Thus, a negative arc drop in an externally heated hot-cathode arc operated on this "ball-of-fire" principle has been obtained. Here, a small region in the inter-electrode space, with a high potential, is formed. The ions formed in this region neutralize the negative space charge in the surrounding dark plasma. An electrode potential exceeding the ionization potential of the gas is required for starting the discharge and, to maintain the discharge, a voltage drop, amounting to several volts, may be required. Although this method of operation may give a negative anode voltage (by using a tungsten cathode and a barium-covered nickel anode), this process of ion generation is quite inefficient.

A more efficient method of ion generation is by the injection of ions from an auxiliary discharge, this being the principle of operation used in the plasmatron. Results obtained in plasmatron studies indicate that the current in the auxiliary discharge is of the order of 1% of

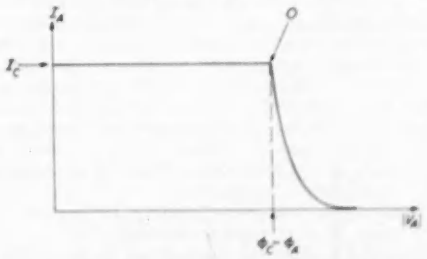

Fig. 2. **Theoretical volt-ampere characteristic of a thermionic energy converter.**

the main discharge current. The auxiliary discharge voltage was about 50 V, and the auxiliary discharge required a cathode heater power of the order of 50 W/A. This adds up to about 1 W/A of main discharge current. This energy must be delivered in the form of electrical energy to the system and could in principle be taken from the output power of the converter. Compared with the ball-of-fire method of operation, this method of ion generation would be at least twice as efficient.

The method of ion generation used in the energy converter described in this paper is based on the phenomenon of resonance ionization. A gas whose ionization potential V_i is lower than the work function of the cathode Φ_C is introduced into the tube. When the condition $\Phi_C > V_i$ is satisfied, neutral atoms striking the hot cathode will be ionized and injected as positive ions into the inter-electrode space. In this way a plasma beam, which extends from the cathode to the anode, is formed. For complete neutralization, the ion density must equal the electron density. The power lost in ion generation may be of the order of a few hundredths of a watt per ampere, i.e., one or two orders of magnitude better than the ion-generation methods previously mentioned.

Experimental Studies of a Thermionic Energy Converter

The experimental tube used in these studies is shown schematically in Fig. 3. This tube, which contains caesium vapour, is a coaxial diode with a nickel anode A of 0·1 in. i.d. and a directly heated tungsten ribbon cathode B of 0·04 × 0·002 in. section. A caesium reservoir is introduced into the tube, after tube processing by the reduction of caesium dichromate, the amount of caesium in the tube being sufficient to yield the vapour pressure in equilibrium with liquid caesium for the range of ambient temperatures used.

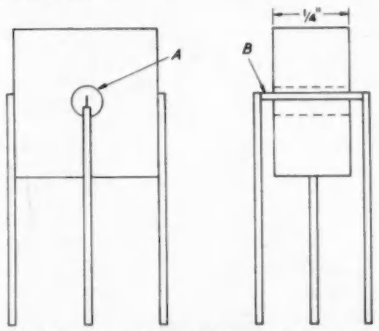

Fig. 3. Schematic diagram of the electrode structure of the thermionic energy converter used.

The caesium in the tube serves two purposes, i.e., (1) it provides an ion source owing to resonance ionization at the cathode ; with $\Phi_C = 4{\cdot}52$ V for tungsten and $V_i = 3{\cdot}89$ V for caesium, the condition for resonance ionization $\Phi_C > V_i$ is satisfied, and (2) caesium condenses on the cold anode and provides a covering which reduces the anode work function to a value approximately equal to the work function of caesium, i.e., $\Phi_A = 1{\cdot}81$ V. For sufficient coverage it is essential that the anode be kept near the ambient temperature.

The vapour pressure p [mm Hg] of caesium in the tube depends on the gas temperature T_g [°K] and the electron current density j_A [A/cm²] and can be found from

$$p = 4{\cdot}12 \times 10^{-6} j_A \sqrt{T_g} \quad .. \quad .. \quad (1)$$

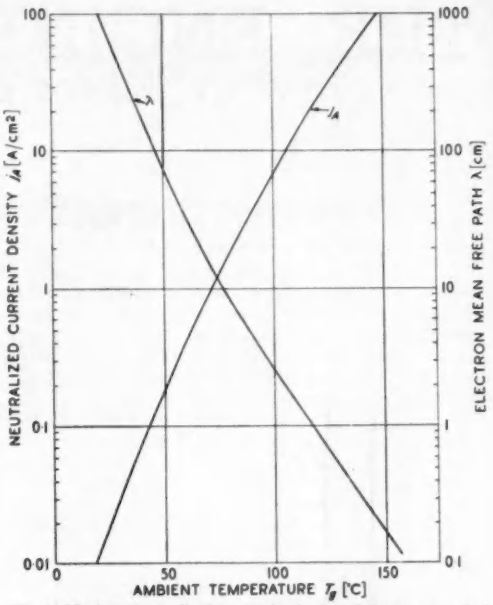

Fig. 4. Maximum neutralized current density j_A and electron mean free path λ in caesium vapour, as a function of ambient temperature T_g.

Consequently, eq. (1) sets a lower limit on the ambient temperature for a certain electron current density. From vapour-pressure data on caesium, eq. (1) is plotted in Fig. 4, which shows maximum neutralized current density j_A in caesium vapour as a function of ambient temperature T_g [°C], and also the electron mean free path λ [cm]. From Fig. 4 it can be seen that, for current densities of interest, i.e., up to 10 A/cm², ambient temperatures up to about 110° C are required, and these were achieved experimentally by placing the tube in an oven. Once the optimum temperature is reached, the anode current is quite insensitive to temperature, until at higher temperatures the current decreases, owing to back-scattering of electrons. Although the cathode-to-anode distance is not critical, it is desirable to choose this distance shorter than the mean free path, in order to reduce back-scattering. In the experimental tube the average cathode-to-anode distance was about 1·2 mm.

A special circuit was used for performance studies of the energy converter. Energy was supplied to the cathode in the form of joule heat and, as it was essential that no voltage gradient existed along the cathode during measurements of anode current and voltage, the filament was heated by a half-wave rectified 400-cps current. The anode current and anode voltage were measured during the off part of the a.c. cycle by displaying the volt-ampere characteristic on an oscilloscope, the grid of the oscilloscope being modulated to give high brightness only during the off part of the a.c. cycle. The volt-ampere characteristic was displayed by varying a load resistor from zero to a high value. The temperature of the cathode was measured with an optical pyrometer and cross-checked with the data on current density. A further temperature check was obtained from resistance measurements on the filament.

Volt-ampere characteristics were found to follow predicted characteristics quite well. In a typical characteristic, the anode voltage was constant up to about

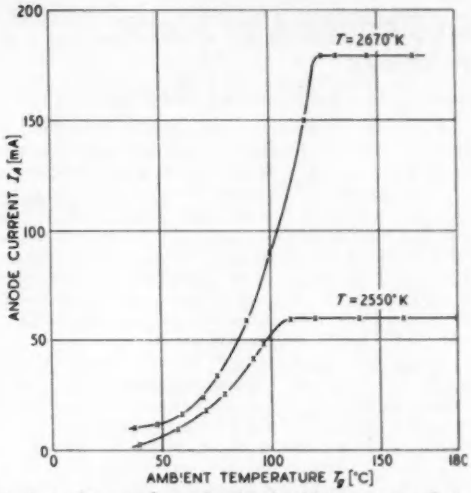

Fig. 5. Anode current I_A as a function of ambient temperature T_g, for different values of cathode temperature T.

2·5 V, i.e., approximately equal to the contact difference of potential $\Phi_C - \Phi_A = 2{\cdot}7$ V. Application of an external positive voltage to the anode was found to produce no appreciable change in the maximum current, showing that the condition $I_A = I_C$ is very nearly fulfilled.

The ambient temperatures necessary for space-charge neutralization were experimentally determined. Fig. 5 is a plot of emission current against ambient temperature with cathode temperature T as parameter. Current saturation occurred at slightly higher temperatures than those predicted by eq. (1) and Fig. 4. This is believed to be due to the fact that a slight voltage gradient existed along the filament as a result of the part of the discharge current which had to flow to one end of the filament. This voltage gradient causes a transverse flow of ions and corresponds to an ion drainage. A falling-off of the anode current because of back-scattering was not noticeable for a fairly large temperature range, indicating that the ambient temperature is not a critical parameter.

Measurements of maximum conversion efficiency η (at an anode voltage of 2·5 V) as a function of cathode temperature T were also made. Agreement between theory and experiment was satisfactory, as can be seen from Fig. 6, which shows the theoretical curve of efficiency and the actual experimental results. Measurements could not be extended beyond $\eta = 10{\cdot}5\%$, because of current instabilities, which are believed to be due to the presence of a voltage gradient along the cathode as a result of discharge current flowing through the filament, causing an appreciable disturbance in the ion flow. This difficulty may be eliminated by using a heavier filament.

As can be seen from Fig. 6, efficiency increases with cathode temperature. However, the evaporation rate of cathode material also increases with temperature. Thus, according to published values, the evaporation rate per 1000 hr of tungsten is, for example, 0·00015 mm thickness at 2300° K, 0·0038 mm at 2500° K, 1·81 mm at 3000° K, 12·4 mm at 3200° K, and 66·6 mm at 3400° K. Clearly, then, a compromise must be made between the desired efficiency and the life of the converter. Exactly how much material can be evaporated before the operation of the tube is seriously disturbed is difficult to estimate. Experience with the present tube indicates that the anode work

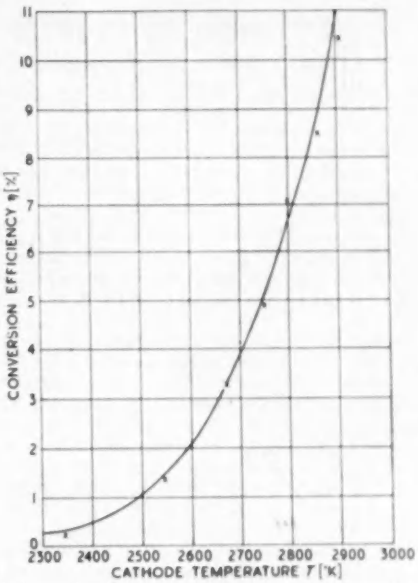

Fig. 6. Conversion efficiency η as a function of cathode temperature T.

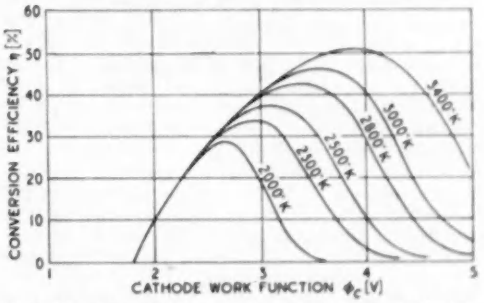

Fig. 7. Conversion efficiency η as a function of cathode work function Φ_C, for different values of cathode temperature T.

function is not seriously affected by the tungsten deposit. An ultimate evaluation can be effected only by actual life tests of a converter in its specific application. The conventional technique of lowering the evaporation rate by introducing a buffer gas is believed to be unsuccessful in this case, because the accompanying back-scattering of electrons would lower the efficiency.

Materials Problems of the Thermionic Energy Converter and its Applications

As discussed in the previous section, operation of the thermionic energy converter at high conversion efficiencies using a tungsten cathode is incompatible with long tube life. Also, the high cathode temperature required for high efficiencies limits the application of the converter. High conversion efficiencies at lower temperatures call for a lower anode work function and/or a less power consuming emitter. Of particular importance is the latter requirement. For a visualization of the cathode problem, assume an emitter having all properties the same as those of tungsten, except for the work function. Fig. 7 shows conversion efficiency η plotted

(Concluded on page 350)

Diffusion of Aluminium and Beryllium in Nickel and Nickel Alloys

By H. Bückle and J. Moisan. (From *La Recherche Aéronautique*, No. 64, 1958, pp. 27–33, 13 illustrations.)

The solubility of aluminium and beryllium in nickel is too low to enable good oxidation resistance to be obtained with the layers of solid solutions produced by the usual diffusion processes. In this paper, a new diffusion process is described, by means of which surface layers of definite compounds of aluminium and beryllium (AlNi, $AlNi_3$, and BeNi, Be_4Ni) can be applied on nickel. Details are given of the behaviour of these layers at high temperatures in air and in the presence of combustion gases.

Diffusion processes for the formation of protective surface layers on metals have been known for a long time. The layers obtained by these processes are characterized by a continuous variation of composition and physical properties, from the surface towards the interior of the treated materials. The layers consist of solid solutions of a base metal with an element which serves as a " donor ". Since the concentration of the donor element can never exceed the solubility limit of the solid state, improvement in the properties of the base metal is limited when the solubility of the donor in the metal is fairly low. This occurs in the case of the diffusion of aluminium (solubility 5 to 6%) or beryllium (about 2%) in nickel. In contrast, calorized iron has an excellent oxidation resistance, since iron can absorb up to 35% of aluminium in a solid solution.

To provide nickel with surface layers having a high aluminium or beryllium content, it was decided to use the " multi-phase diffusion " process[1,2,3,4] developed by ONERA. This process follows a trend opposite to that usually considered in technological work, inasmuch as the formation of layers of definite compounds is generally avoided, whereas in the new process all measures are adopted which can contribute to the formation of such compounds. Because these compounds consist of phases differing from that of the base metal, a much wider choice of surface properties is available.

Aluminium-Nickel Layers

Fig. 1 shows the nickel-aluminium phase diagram, which is dominated by the δ-phase. As this phase has a very good oxidation resistance and is fairly hard, without being too brittle, it was decided to use this phase as a protective surface layer.

An investigation was made of the layers obtained by bringing a sample of nickel into contact with a liquid alloy of aluminium saturated with nickel (70% Al, 30%Ni) at 900°C. The specimen was exposed to six hours' treatment at 900°C, followed by slow cooling. It was then cut in the direction perpendicular to its surface, and Vickers microhardness tests were made over a polished section, using a constant load of 50 grams. It was found that the nickel, with a Vickers hardness of 100 kg/mm², was covered with a first layer of γ-phase (Al_3Ni_2), 400 μ thick, with a hardness of about 580 kg/mm², followed by a thin layer of β-phase (Al_3Ni), 25 μ thick, with a hardness of 460 kg/mm², and an outermost layer of 70 Al/30 Ni alloy, 180 μ thick, with a hardness of some 60 kg/mm². The δ (AlNi) and ε ($AlNi_3$) phases were not formed. This result was unexpected, since theoretically the physico-chemical conditions were in favour of the formation of the δ-phase. No explanation can be offered for this anomaly.

In practice, it was found necessary to avoid the formation of the γ- and β-phases, which are too fragile, and to promote the formation of the δ- and ε-phases, and this was achieved by reducing the aluminium contribution of the donor. It was possible to provide nickel with a surface layer of δ-phase and a sub-layer of ε-phase, by using a donor consisting of a mixture of aluminium powder and alumina powder. However, the layers thus obtained exhibited irregularities owing to local coalescing of aluminium particles, which are liquid at the temperatures of 900 to 950°C used in the tests.

To overcome this difficulty, a donor was developed which contained only 10% of free aluminium, the remainder consisting of Ni_2Al_3 (δ-phase) with a melting point of 1120°C. This donor was used in the form of a very fine powder, with a slight addition to aluminium trifluoride. The nickel specimen was dipped into a thick bed of the powdered donor and then heated in a hydrogen atmosphere at a temperature between 800 and 1000°C. The duration of this treatment depends on the temperature used and also on the desired layer thickness. Thus, a treatment of 90 min at 950°C gives a surface layer of AlNi, 40 μ thick, with a sub-layer of $AlNi_3$, 4 μ thick. The layer thickness increases proportionately to the square root of the time of treatment. With a donor consisting solely of powder of the γ-phase (Al_3Ni_2) without addition of free aluminium or aluminium trifluoride, the layer obtained consists entirely of ε-phase ($AlNi_3$), and its thickness is 20 μ after 4 hr at 950°C.

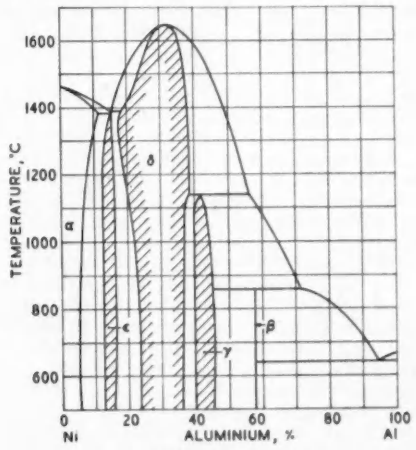

Fig. 1. Nickel-aluminium phase diagram.

AlNi layers can also be produced by a diffusion process in the vapour phase. The donor gas, aluminium monofluoride (AlF), is generated in a mixture of aluminium and aluminium trifluoride. At 900°C, the volatility of the trifluoride is relatively low, whereas the monofluoride is in the vapour state. The treatment can take place either under high vacuum or in a hydrogen atmosphere. When in contact with nickel, the monofluoride decomposes catalytically; the aluminium thus released reacts with the nickel and forms well-defined Al_xNi_y compounds (surface layers of AlNi and sub-layers of

$AlNi_3$). At present, this method is still a rather delicate operation, particularly as regards specified values of layer thickness, and hence requires further development. For the time being, therefore, it is preferable to use the diffusion process with a solid donor, and this gives very satisfactory results.

Beryllium-Nickel Layers

Fig. 2 shows the nickel-beryllium phase diagram, which comprises two definite phases, i.e., the β-phase (BeNi) and the γ-phase (Be_4Ni). Surface layers consisting of either of these compounds can be obtained by suitable treatments, according to requirements. The donor used is freshly ground beryllium powder, with an addition of from 2 to 10% of ammonium fluoride or calcium fluoride, to eliminate any air in the powder and as a deoxidizer. The nickel specimen was dipped into a thick bed of powder and then heated in a hydrogen atmosphere at a temperature between 800 and 1000°C. After a one-hour treatment at 800°C, a surface layer of Be_4Ni, 25 μ thick, was obtained, with a sub-layer of BeNi, 3 μ thick. To obtain a layer consisting solely of the BeNi phase, the piece was subjected to a second treatment at 1000°C, without a further addition of beryllium.

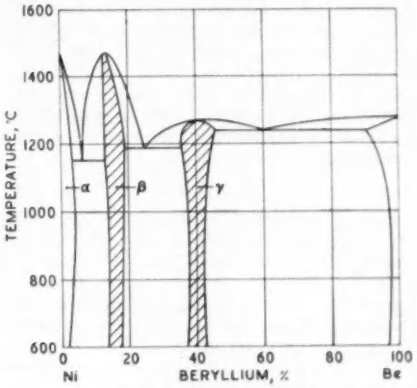

Fig. 2. Nickel-beryllium phase diagram.

It may be noted that aluminium and beryllium surface layers can also be applied on modified nickel-chromium 80/20 alloys, by the same methods as for pure nickel. The layers, however, then no longer consist completely of a single phase but include precipitated particles containing chromium or titanium, which are present in these alloys. The results given in the following refer to Nimonic 75, the approximate composition of which is 20% Cr, 0·6% Ti, 0·2% Al, and 79·2% Ni.

Results of Investigation

Samples of Nimonic 75 with surface layers of Al_xNi_y applied by means of the above treatments were examined. A photomicrograph of a section (Fig. 3) of a sample shows a δ-layer (AlNi) of 180 μ thickness. The inner portions of the layer and particularly the region near the Nimonic core show the precipitations mentioned above, as well as a thin ε-sub-layer overlapping with the precipitation zone.

Further investigation showed that the evolution of the layers may be summed up as follows :—In the first period of treatment, a sub-layer of ε-phase ($AlNi_3$) develops, at the expense of some of the δ-phase (AlNi). Then the ε-phase ($AlNi_3$) spreads out and occupies the entire thickness of the layer. At the same time, the layer thickness increases. Subsequently, the ε-phase is absorbed by the nickel core, which forms solid solutions (α-phase) with the aluminium. The maximum concentration of the α-phase is an equilibrium value (solubility limit) at the surface in contact with the ε-layer ; consequently, this concentration remains constant as long as the slightest trace of the ε-layer exists and is reduced only after complete absorption of the layer.

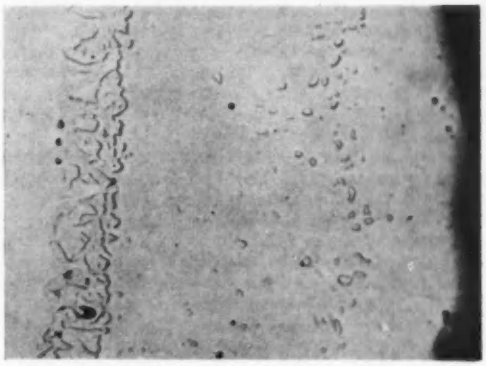

Fig. 3. Nimonic 75 alloy with (right) an $AlNi_3$ layer. (× 350)

The rates of absorption and formation of the various layers (which ultimately determine the behaviour and durability of the surface layers at high temperatures) depend in a complex manner on the diffusion coefficients, which are different for each phase. They can also have different values for the same elements in each phase (Kirkendall's anomaly). Since the diffusion coefficients for the various phases are not known, it is necessary to use empirical methods for determining the rates of absorption of the layers.

The samples of Nimonic 75 from which these results were derived were subjected to an oxidation treatment in air at a constant temperature of 1150°C. All samples were initially provided with an AlNi layer of 150 μ thickness. This layer was completely absorbed by the ε-phase ($AlNi_3$) after 25 hr treatment, the ε-phase lasting 150 hr. These findings indicate that, at least at elevated temperatures, it is not possible to rely on the favourable protective properties of the AlNi layer, in view of its brief duration.

Nevertheless, the AlNi phase can be regarded to some extent as a " reservoir " of aluminium, which not only increases the total life of the layers but also contributes to the formation of a superficial skin of alumina, which, because of its density and toughness, acts as a barrier against the ingress of oxygen and does not disappear, even after the absorption of the layers of AlNi and $AlNi_3$.

The skin of alumina, too thin to be visible in photomicrographs, gives a uniformly whitish colouring to the specimen surface, its formation being observed after the first minutes of oxidation treatment at 1150°C. The appearance of the specimens remained unchanged after continuing the treatment for 350 hr, although the layers of definite compounds were absorbed after 150 to 180 hr. The distribution of the phases was indicated more clearly by microhardness curves than by photomicrographs. Thus, after treatment for 75 hr, the outermost layer consisted of $AlNi_3$ (ε-phase), with a thickness of 100 μ and a Vickers microhardness, with a load of 20 grams, of more than 500 kg/mm², progressively dropping to about 380

kg/mm². The ε-phase was followed by an α-phase, more than 400 μ thick, with microhardness values dropping from about 380 kg/mm² to about 240 kg/mm². After 170 hr of treatment, it was found that the ε-layer had disappeared and that the α-layer extended to the outer surface of the specimen, with a microhardness value of more than 360 kg/mm² down to a depth of about 260 μ, followed by a gradual decrease down to about 250 kg/mm² at a depth of about 500 μ, this being the " penetration " depth of the aluminium introduced by diffusion. Incidentally, in this connection, it is interesting to note that an unprotected sample of Nimonic 75, similarly exposed to treatment for 170 hr at 1150°C, was found to have considerably reduced microhardness values, ranging from about 160 kg/mm² at the outer surface to about 250 kg/mm² at a depth of about 500 μ.

It may be said that the layers of AlNi and $AlNi_3$ resisted thermal shock very satisfactorily, protected samples withstanding repeated quenching in cold water from 1150°C without showing any signs of flaking.

The behaviour of protected samples in combustion gases differed completely from their behaviour in air. Thus, after 100 hr of exposure to combustion gases at 850°C, it was found that the AlNi layer disappeared, while the $AlNi_3$ layer was still intact. On the other hand, after treatment at 1000°C for 70 hr, considerable corrosion cracking was produced on the surface of the Nimonic 75 alloy under the layer of $AlNi_3$. This layer was unaffected but had separated from the core, owing to corrosion between the faces. It seems, therefore, that the layer was penetrated by diffusion by some element which was inert relatively to the $AlNi_3$ phase, but which reacted with the Nimonic 75, this element probably being sulphur. It may be noted that internal corrosion begins at 850°C.

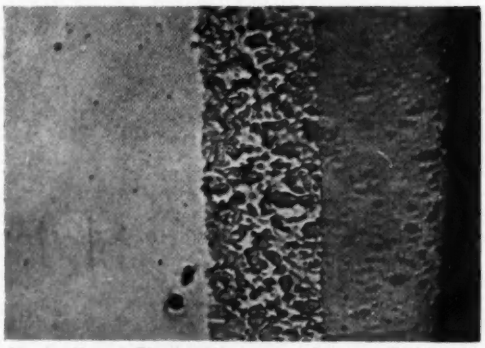

Fig. 4. Nimonic 75 alloy with layers of BeNi and Be_4Ni (right) (× 500)

As regards layers of Be_xNi_y, it was noted that the diffusion process with beryllium always provides two layers, i.e., a surface layer of Be_4Ni of 20 to 30 μ thickness and a sub-layer of BeNi of 3 to 10 μ thickness (Fig. 4). On pure nickel, the layers definitely consist of one phase only, but with the Nimonic alloy they contain a large number of precipitations. Further treatment, without further beryllium additions, results in the development of the sub-layer of BeNi at the expense of the Be_4Ni surface layer, but the absorption rate of the BeNi by the matrix is much lower than that of the $AlNi_3$ phase.

Beryllium-nickel layers are much harder than those of aluminium-nickel. At the surface, the microhardness of the Be_4Ni layer, 25 μ thick, is 1800 to 1900 kg/mm², using a load of 17 grams, this high hardness value being partly due to the presence of precipitations. The intrinsic hardness of the Be_4Ni phase on a pure nickel sample is of the order of 1500 kg/mm². The Be_4Ni surface layer, 25 μ thick, is entirely absorbed by the BeNi sub-layer, which increases from its initial thickness of 7 μ to about 50 μ after a treatment of 1 hr at 1000°C. Although the Be_4Ni layer is present only for a brief period, the BeNi phase, which subsequently becomes the surface layer, has good oxidation resistance and remarkable thermal stability, even in combustion gases.

The BeNi layer was found to be still intact after a treatment of 100 hr at 850°C in combustion gases, and the underlying Nimonic 75 alloy core showed no signs of internal corrosion. Photomicrographs showed that, during treatment, the precipitations diffused out of the BeNi layer and agglomerated along the contact surface between this layer and the core. As a result, the hardness of the protective layer decreased somewhat, ranging from about 650 kg/mm² at the outer surface to 460 kg/mm² at the contact surface, but was still definitely higher than the hardness of an unprotected sample (180 to 240 kg/mm²).

Because of the hardness and brittleness of the precipitations, their agglomeration along the contact surface is extremely detrimental to the mechanical strength of the layer, the protective ability of which becomes uncertain, owing to the risk of cracking and flaking. At temperatures exceeding approximately 1000°C, a tendency to melting occurs in the contact zone between the layer and the core, and it seems that the precipitations form, either with their matrix or with an element brought in by diffusion, a eutectic system having a comparatively low melting point.

Conclusions

Aluminium-nickel and beryllium-nickel can be applied on nickel and its alloys in the form of strongly adherent layers. Layers of $AlNi_3$ protect nickel and its alloys against oxidation in air, but do not protect them against crevice corrosion in combustion gases. Layers of BeNi provide protection in air and are also effective against corrosion in combustion gases, up to temperatures of at least 850°C. However, they deteriorate at higher temperatures, with a risk of flaking.

Further research is being carried out to improve the good inherent properties of these compounds, and specimens have already been produced by partial fusion fritting and liquefaction[5,6], consisting entirely of AlNi or of a mixture of AlNi and $AlNi_3$. These specimens have shown extremely good corrosion resistance and appreciable mechanical strength at high temperatures, but have low resilience and creep strength[7]. Even at the moment, however, it is considered that Al_xNi_y layers and especially the Be_xNi_y layers applied on nickel and its alloys may offer interesting prospects for other applications, where good use can be made of their high hardness, associated with their good resistance to oxidation in air.

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The Dynamics of Gears with Feather Keys

By B. Szőke. (From *Acta Technica Academiae Scientiarum Hungaricae*, Vol. 21, Nos. 1 & 2, 1958, pp. 11–25, 12 illustrations.)

When investigating effects in gears such as noise, oscillations, breakages, etc., the dynamics of the forces on feather keys during rotation of the gear have often been overlooked. Since these effects may cause trouble, the object of this paper is to analyse the forces involved.

In a gear, the peripheral force P (Fig. 1a), and hence the load Q acting on a tooth, occupy a fixed position in space in relation to the centre O of the shaft. On the other hand, the key, rotating with the shaft of radius r, causes a shaft reaction A, balancing the tooth load Q acting on the gear-wheel, and the key force E will vary during each revolution.

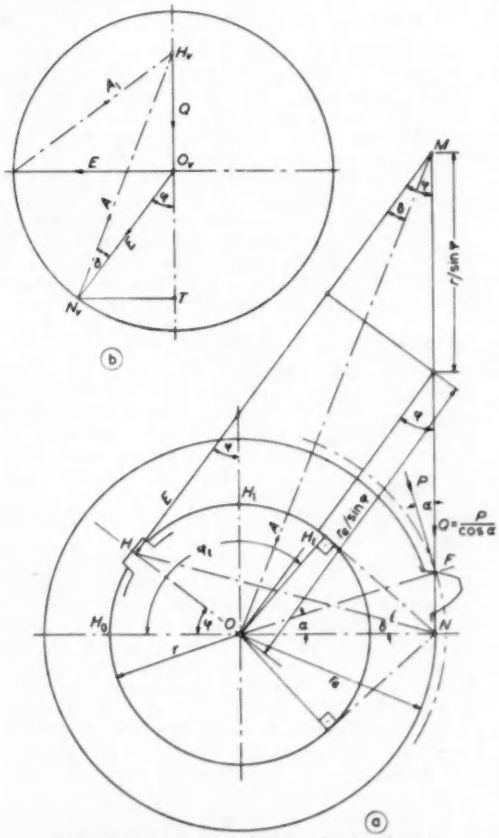

Fig. 1. Determination of shaft reaction in a keyed gear.

Fig. 1a shows the gear in a position where the key has turned through an angle φ from point H_0, which is chosen in such a way that the centre-line H_0O of the key is at right angles to the tooth load Q, so that $Q = P/\cos\alpha$, where P is the circumferential force acting at the contact point F, and α is the pressure angle. The straight line of force Q, i.e., the contact line, touches the base circle of radius r_a at point N.

Consequently, the direction of the resultant force A, which acts on the centre of the gear-wheel, is indicated by the line OM in Fig. 1a, and its magnitude is determined by the vector diagram in Fig. 1b with respect to a known force Q.

This resultant A can also be computed easily for any arbitrary angle φ. From Figs. 1a and 1b, it will be seen from similar triangles that $H_vN_v/H_vO_v = HN/HO$, from which it will be found that

$$A = \frac{Q}{r}\sqrt{r^2 + r_a^2 + 2r\,r_a\cos\varphi} \qquad .. \quad (1)$$

Furthermore,

$$E = Q\,r_a/r \qquad .. \quad .. \quad .. \quad (2)$$

From eq. (1), the following limiting cases can be established :—

With $\varphi = 0$ deg., $A = \frac{Q}{r}(r_a + r) = E + Q$

With $\varphi = 90$ deg., $A = \frac{Q}{r}\sqrt{r^2 + r_a^2} = E\sqrt{1 + \left(\frac{r}{r_a}\right)^2}$

With $\varphi = 180$ deg., $A = \frac{Q}{r}(r_a - r) = E - Q$

With $\varphi = 270$ deg., $A = \frac{Q}{r}\sqrt{r^2 + r_a^2} = E\sqrt{1 + \left(\frac{r}{r_a}\right)^2}$

Consequently, the following statements can be made :—

(1) Key force E is a rotating vector, which does not change its magnitude during shaft rotation and which lags 90 deg. behind the mean radius OH of the key (Fig. 1a), its angular velocity being equal to that of the shaft, and the end point N_v of its vector describing a circle of centre O_v and radius E (Fig. 1b).

(2) Vector Q of the tooth load is stationary. Neglecting exceptional cases, the radius of the pitch circle is greater than that of the shaft or of the key, so that $Q = H_vO_v < E = O_vN_v$.

(3) Shaft reaction A is also a rotating vector, its centre being at H_v, but its angular velocity is not the same as that of the shaft. Its magnitude is not constant, but exerts a pulsating effect on the hub. Its rotating end point is that of vector E, but its stationary origin coincides with that of vector Q.

Fig. 2 shows the variation in shaft reaction A acting on the bore for every 45 deg. of one revolution and for each position, and also shows where the pressure is taken up in relation to the key seat.

A clearer idea of the amplitudes of the pulsations of shaft reaction A is obtained if the variation in shaft load is plotted in terms of angle φ, as shown in Fig. 3.

On the basis of Fig. 2, the following may be stated :—

(1) During rotation, the same half of the hub is always subjected to pressure.

(2) From position 0 to position 4 in Fig. 2, the shaft load decreases, and the key tends to press itself into its seat ; during the other half revolution, the shaft load increases, and the key attempts to pull itself out of its seat. This inward and outward motion is most pronounced in a position where force A makes the smallest angle with the middle plane

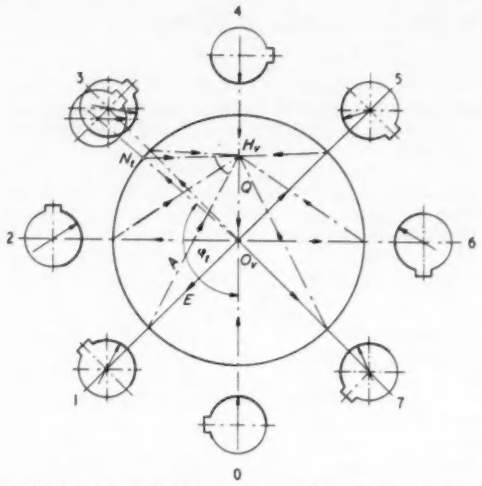

Fig. 2. Variation of the direction of shaft reaction relative to the centre-line of the key during one revolution.

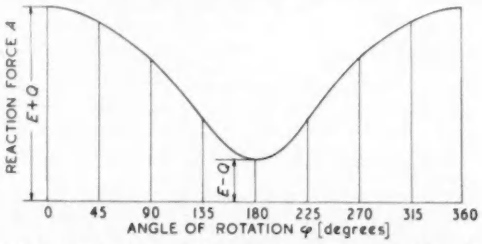

Fig. 3. Variation of the magnitude of shaft reaction in terms of the angle of rotation.

OH of the key. As shown in Figs. 1a and 1b, angle $MOH = 90 - \delta$, and will be smallest when the value of δ, which equals angle $O_vN_vH_v$ or angle ONH, is at its highest, i.e., at position φ_t of angle φ, where NH_t contacts the circle of radius r and angle OHN is a right angle (at point H_t).

(3) In Fig. 2, the vector $A = N_tH_v$, at right angles to O_vH_v, yields a shaft reaction whose direction includes the minimum angle with the middle plane OH of the key during the first half revolution. At this extreme value, it is evident from Fig. 1a that

$$\cos \varphi_t = -\cos (180 - \varphi_t) = \frac{r}{r_a} = \frac{Q}{E} \quad .. \quad .. \quad (3)$$

and, at this position, from Fig. 2,

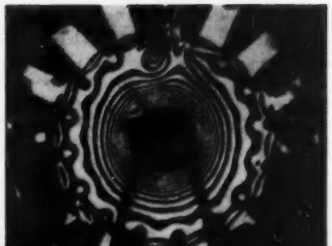

Fig. 4. Photo-elastic stress pattern of a gear force-fitted to a shaft.

Fig. 5. Photo-elastic stress pattern of a gear mounted on a shaft with a feather key.

$$A = \sqrt{E^2 - Q^2} = E \sin \varphi_t \quad .. \quad .. \quad (4)$$

Incidentally, it should be noted that photo-elastic investigations of transparent plastic gear models, using polarized light, clearly show the distribution of the power impulses arising in gears and confirm the findings described in this paper. Thus, Fig. 4 shows the stress distribution in the body of a gear which has been forced onto a shaft, without using a key, while Fig. 5 shows the distribution in a gear mounted on the shaft with a feather key. In both cases, the top tooth was loaded by a pressure from left to right. In Fig. 4, it will be seen that the patterns take the form of regular circles surrounding the shaft. In Fig. 5, the effects of key force E and shaft reaction A manifest themselves.

Probable Effects of Dynamic Forces

In large gears, where force Q is relatively small, compared with the value of E, the angle characteristic from the point of view of wheel slip becomes of importance only after the first quarter revolution as, up to this stage, it cannot have much influence because the reaction force A is almost perpendicular to the middle plane of the key. This, however, does not necessarily apply in the case of small gears, particularly when they are running at high speeds.

From eq. (2), if the scale is so chosen that $Q = r$, $E = r_a$. Now, as indicated in Fig. 6, which shows the stages of displacement of the wheel body in relation to the shaft, if the angle of friction ρ between the key and the keyway is drawn from any point K, e.g., K_3, on the periphery of a circle of radius r_a, it will be seen that $r_0 = r_a \sin \rho$. If a circle O-L-S-L', whose diameter equals the shaft radius r, is drawn, then, for the angle δ included by forces E and A, $\sin \delta = OL/OK = p/r_a$. In other words during the course of rotation of the vector A about the pole S, the side OL of triangle OSL, i.e., the value of p, varies proportionally with the value of $\sin \delta$.

In the position K_1S, corresponding to δ_{max}, the tangent to the circle of radius r is of particular importance, since the values of δ for shaft reactions KS and K_2S are equal, as the value of p is unchanged. Consequently, at these positions, the conditions for slip are identical.

On the other hand, in mirror-image positions, in relation to OS, such as KS and $K'S$, the force acting on one side at an angle of $(90 - \delta)$ tends to press the keyed half of the shaft against the wheel hub, whereas, on the other side, a force of the same magnitude, acting at an angle of $(90 + \delta)$, attempts to pull it away from the hub.

Two tangents drawn from pole S to the friction circle of radius r_0 produce four points, i.e., K_1, K_1', K_3, and K_3',

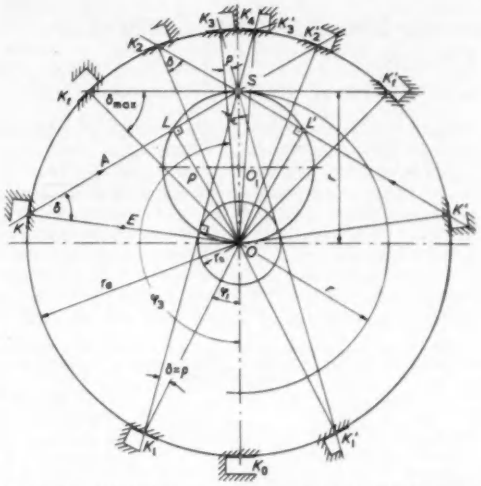

Fig. 6. **Stages of displacement of the body of a gear-wheel in relation to the shaft.**

on the circle of radius r_a. Between K_1' and K_1, the shaft reaction A falls inside the friction cone, so that no slip is possible at the key seat. From K_1 to K_3, the body of the wheel moves radially in relation to the shaft centre. From K_3 to K_3', a tight fit is again obtained, while, from K_3' to K_1', the body of the wheel moves radially in the opposite direction. No matter how slight the friction may be, there is no slip in positions K_0 and K_4.

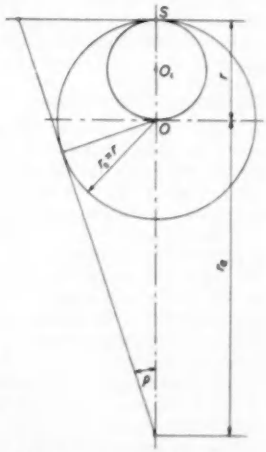

Fig. 7. **Limiting case of displacement of a gear-wheel body in relation to the shaft.**

The angle $K_0OK_1 = \varphi_1$ is the angle at which slip is initiated. It will be seen that

$$\sin \varepsilon = \frac{r_a \sin \rho}{r} = \frac{r_0}{r} \qquad .. \quad .. \quad (6)$$

and that

$$\varphi_1 = \varepsilon + \rho \qquad .. \quad .. \quad (7)$$

Now, angle $OSK_3 = 180 - \varepsilon$, angle $K_4OK_3 = 180 - \varphi_3$, and φ_3 = angle $K_0OK_3 = 180 - \varepsilon + \rho$, so that the angle within which slip takes place is angle $K_1OK_3 = \varphi_3 - \varphi_1 = 180 - 2\varepsilon$.

Fig. 7 shows the limiting case of displacement of the body of the gear-wheel in relation to the shaft. From Figs. 6 and 7, the limiting position at which movement still takes place occurs when $r_0 < r$. In other words, as $r_0 = r_a \sin \rho$,

$$r_a < r/\sin \rho \qquad .. \quad .. \quad .. \quad (8)$$

and from Fig. 7, the limiting position is expressed by

$$\tan \rho = \mu = \frac{r}{\sqrt{r_a^2 - r^2}} \qquad .. \quad .. \quad (9)$$

If the value of sin ρ is taken as 0·1, the effects described may occur in all gears seated loosely on shafts whose pitch-circle diameter is not more than ten times the bore. Gears of such dimensions are common in motor vehicles, machine tools, and in most sliding-type gearboxes.

Consequences of Slip Caused by Pulsating Shaft Reaction

From Fig. 2, it will be seen that, in some instances, loosening of keys (particularly likely in the case of reversing shafts) can be brought about not only by the direct action of force E on the key but can actually be increased by the resultant A of key force E and tooth load Q, especially if the fit of the shaft and bore is inadequate, or if it is too loose for service requirements, thereby permitting radial movement of the key.

With regard to sliding-type gearboxes, where easier-fitting gears are necessary, pulsatory effects merit special attention. Thus, the need for a bigger shaft for the larger gear, in order to transmit the higher torque involved, may cause radial movement of the wheel body in relation to the shaft centre to occur with the fast-running pinion, as well as with the comparatively slow-running large gear. The distance between mating gears therefore varies rhythmically, according to the speed of the pinion and the gear ratio. The effect of the vibration produced may also be a source of noise.

With shafts of 50 to 60 mm in diameter in sliding-type gearboxes, a clearance of from 0·04 to 0·05 mm is quite likely between the wheel bore and shaft, so that, in the two mating gears, a relative displacement of the order of 0·1 mm can arise, even if the gears are very accurately cut and balanced. Another source of noise may be hammering of the wheel body against its own shaft, this being repeated, as already mentioned, twice per revolution.

Naturally, the effects described in this paper cannot arise in the case of gears fitted with two accurately seated opposed sliding keys or with splined shafts of extremely uniform fit. Such accuracy is, however, very unlikely under normal production conditions, and it is therefore quite reasonable to suppose that gear noise can arise even with gears fitted with opposed sliding keys or splines. At the same time, it should nevertheless be mentioned that some cases of noise have been erroneously attributed to errors in gear cutting or to hammering caused by unbalance when, in fact, they are really due to vibrations caused by a defective clutch.

The above considerations also provide a possible answer to a phenomenon sometimes occurring in practice, where, after an investigation of gear noise, the trouble has been found to be apparently cured after re-assembly of the unit, without, however, any actual remedial measures being taken. This is probably due to the fact that, after re-assembly, the gears may have been mounted on the splined shaft in a different position from the original and may accidentally have acquired a more uniform fit.

SWITZERLAND

The Influence of Fillet Radius on the Fatigue Strength of Spur Gears

By H. GLAUBITZ. (From *Schweizer Archiv*, Vol. 24, No. 5, May 1958, pp. 151–162, 19 illustrations.)

DESPITE its undoubted influence on fatigue strength, the fillet radius of straight spur gears is still chosen fairly arbitrarily. A large radius is generally advantageous, and its maximum value is obtained by the use of a generating cutter with a rounded tip. A standard rack-type cutter (Fig. 1) with a pressure angle α of 20 deg. or 30 deg. can have a maximum tip radius ρ_w of $0{\cdot}45/P$ or $0{\cdot}245/P$ respectively, where P is the diametral pitch, and the corresponding fillet radius ρ of the cut gear will be slightly larger. Nevertheless, generally accepted practice adopts a radius of only $0{\cdot}2/P$ for a pressure angle α of 20 deg., and even the German standards recommend hobs with tips rounded to $0{\cdot}2/P$*.

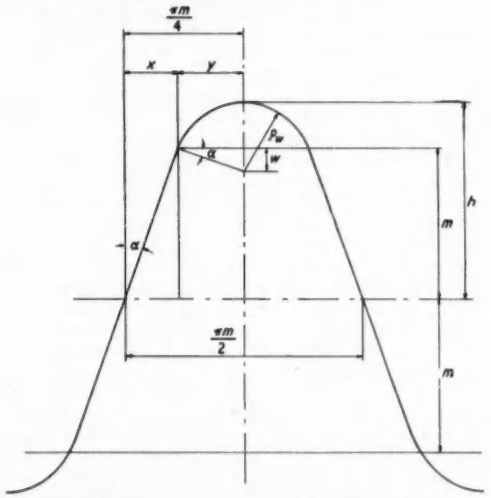

Fig. 1. **Standard rack-type gear cutter with maximum tip radius ρ_w.**
$m = 1/P$ = half working depth, h = tip height.
$x = m \tan \alpha$.
$\rho_w = y \sec \alpha = (\pi m/4 - m \tan \alpha) \sec \alpha$.

The surface roughness of the fillet also has a large influence on fatigue strength; in practice, it varies widely from 1μ for polished fillets to 50μ for shaped or milled fillets with rough scratches.

According to some early German gear fatigue tests[1], an increase in the fillet radius from the normal to its maximum value doubles fatigue strength, and additional polishing of the fillet increases it to 2·8 times the normal strength. Later investigators, it is true, have not confirmed these high figures. Photoelastic model tests[2] have shown for $\rho = 0{\cdot}2/P$ a stress concentration factor of 1·9, and for the maximum radius (circular root) a factor of only 1·55, i.e., an increase in strength of 23%. The corresponding pulsator tests on steel gears have not shown this improvement, but have established that polishing of the fillets slightly increases the strength of soft teeth, and increases that of case-hardened teeth by 43%. Bending fatigue tests on straight circular bars[3,4] indicate that, if the fatigue strength of polished bars is taken as 100%, the strength of rough-turned bars is only 65% for hardened and tempered steel and 72% for mild steels. Some of the results of running tests on gears[5] are given in Table I, which is based on the use of case-hardened Cr-Mn steel gears with 19 teeth, a face width of ¾ in., a pressure angle $\alpha = 20$ deg., a diametral pitch $P = 1/m = 8$, where m = module [in.], and a profile modification $x = +0{\cdot}75/P$. These results also show the influence of fillet radius ρ and fillet surface quality.

TABLE I: INFLUENCE OF ROOT FILLET RADIUS AND FILLET SURFACE ROUGHNESS ON THE BENDING FATIGUE STRENGTH OF GEARS IN RUNNING TESTS.

Fillet Surface	$\rho/m = \rho P$	Relative Fatigue Strength [%]
Ground	0·1	100
Ground and polished	0·1	110
Ground	0·23	133
Ground slightly with special tools	0·3	133
Flank ground, fillet as-hardened	0·2	158

The increased fatigue strength in the case of the last-mentioned fillet surface in Table I is remarkable, inasmuch as the gears must have had a stress-raising shoulder or recess at the lower end of the ground flank. Finally, two photoelastic investigations[6,7] have indicated a decrease in stress concentration of 20% or 25% for an increase in $\rho/m = \rho P$ from 0·1 to 0·4, or from 0·2 to 0·5, respectively. It should be noted that ρ/m denotes the "specific fillet radius", i.e., the radius in a gear of unit diametral pitch. This specific value divided by the diametral pitch gives the actual fillet radius for any spur gear.

INFLUENCE OF FILLET RADIUS

If the stress-concentration factor α_k determined in the tests just mentioned is plotted as a function of the specific root fillet radius, an approximately hyperbolic relationship $\alpha_k{}^n = (\rho/m)_1/(\rho/m)_2$ is obtained for the change in α_k with a change in (ρ/m) under otherwise constant conditions. As a further approximation, the different notch sensitivities of steels may be ignored, and the stress-concentration factors from fatigue tests assumed to vary in the same manner as those found photoelastically.[8] Since, in this case, the sole interest is in a comparison of various α_k-values, α_k may be taken as unity for, as an example, the average practical value $(\rho/m)_1 = 0{\cdot}2$, thus excluding other influences which would enter with a more theoretical definition of the stress-concentration factor.

For an approximate quantitative comparison, these test results have yielded the following empirical relation:

$$\alpha_k{}^n = \frac{0{\cdot}2}{\rho/m} \quad .. \quad .. \quad .. \quad .. \quad (1)$$

For hardened gears $n = 4$; for unhardened gears, experience indicates a slightly higher value of n (about 5), i.e., the influence of the root fillet radius is slightly less.

It follows from eq. (1) that an increase in the fillet radius from $\rho/m = 0{\cdot}2$ to a fully circular root with $\rho/m = 0{\cdot}4$ to $0{\cdot}5$ reduces α_k (and increases fatigue strength) for hardened gears by about 20%, and for unhardened gears by 15% or less. Lloyds specification of $\rho/m \geq 0{\cdot}377$ gives a 15% higher fatigue strength for

*The British standard 20-deg. basic rack profile shows $\rho = 0{\cdot}39/P$; for profile-milled teeth $0{\cdot}25/P$ is allowed. The American A.G.M.A. 14½-deg. basic rack specifies only $\rho \geq 0{\cdot}209/P$. Lloyds Register of Shipping specifies $\rho \geq 0{\cdot}377/P$ (i.e., 12% of circular pitch).

hardened gears than the average $\rho/m = 0{\cdot}2$. Very small fillet radii, on the other hand, lead to a very pronounced reduction in fatigue strength. Thus, for $\rho/m = 0{\cdot}05$, only 60% of the value for $\rho/m = 0{\cdot}2$ is obtained, and still smaller fillets result in a further very sharp drop. Hence, $\rho/m = 0{\cdot}2$ should be accepted as a minimum value for sufficient strength. In practice, little experience is available on the generation of teeth with a rounded cutter of the type shown in Fig. 1. The author[2] has found no difficulty in generating teeth with such cutters and, if tool life is not reduced, the larger fillet radii give an increase in gear life at no extra production cost.

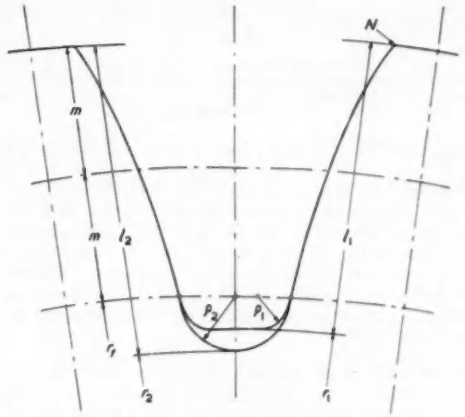

Fig. 2. Flat and circular shapes of the root of spur gears.

It is true that the full advantage of an increase in fillet radius cannot be obtained, because a larger fillet leads to a smaller root circle, and hence to a larger bending lever arm of the tooth load (Fig. 2). A simplified comparison, showing the possible order of magnitude of this effect is as follows :— Assume the tooth load N to act at the tip of a tooth of $2m = 2/P$ working depth with adjoining fillet radius $\rho_1 = 0{\cdot}2m$ or $\rho_2 = 0{\cdot}5m$ respectively. The stress-concentration factors from photoelastic tests[2] then are $\alpha_{k1} = 1{\cdot}9$ and $\alpha_{k2} = 1{\cdot}55$, and the bending lever arms are $l_1 = 2{\cdot}2m$ and $l_2 = 2{\cdot}5m$. Consequently, $(\alpha_{k2}/\alpha_{k1}) = (1{\cdot}55/1{\cdot}9) = 0{\cdot}82$. However, the stress ratio $\sigma_2/\sigma_1 = (2{\cdot}5mN/2{\cdot}2mN) \times (1{\cdot}55/1{\cdot}9) = 0{\cdot}93$, so that, instead of a theoretical strength increase of 18%, a value of only 7% is obtained. However, the increase in fillet radius still remains of more importance than the consequent reduction in the root circle. Incidentally, the reduction due to increased bending lever arms is actually less, because the point of highest concentrated stress occurs near the junction of the flank and fillet, as shown in Fig. 3, where the lever arms differ only slightly.

Owing to the rotation of the gear blank during generation of the teeth, the root fillet radius (ρ/m) is always larger than the generating tool-tip radius (ρ_w/m). A geometrical study of this effect with templates representing basic rack-type cutter profiles of large pitch has yielded the values given in Fig. 4. The gain, i.e., the ratio (ρ/ρ_w) increases with a decreasing pressure angle α and with a decreasing number of teeth on the cut gear. Thus, for example, with a pressure angle α of 20 deg., the cutter with a circular tip ($\rho_w/m = 0{\cdot}45$) has a maximum specific fillet radius (ρ/m) of 0·58, as compared with 0·29 for a flat tip ($\rho_w/m = 0{\cdot}2$), i.e., its value is doubled, and thus, by doubling the reference value of (ρ/m) in eq. (1), the fatigue strength, with a value of n between 4 and 5, is increased by about 16%.

Influence of Fillet Surface

In various tests on gear teeth[1,2,5], including those listed in Table I, only the machining method was known, no details of actual surface-roughness figures being included. However, if the surface roughness is taken to be similar to that of straight circular bars machined in the same way and tested in bending fatigue[3,4], the results appear to fall into line (Fig. 5). Thus, for hardened gears, a rough-machined fillet gives a fatigue-strength value of 70% and a ground fillet 90% that of a polished fillet. For

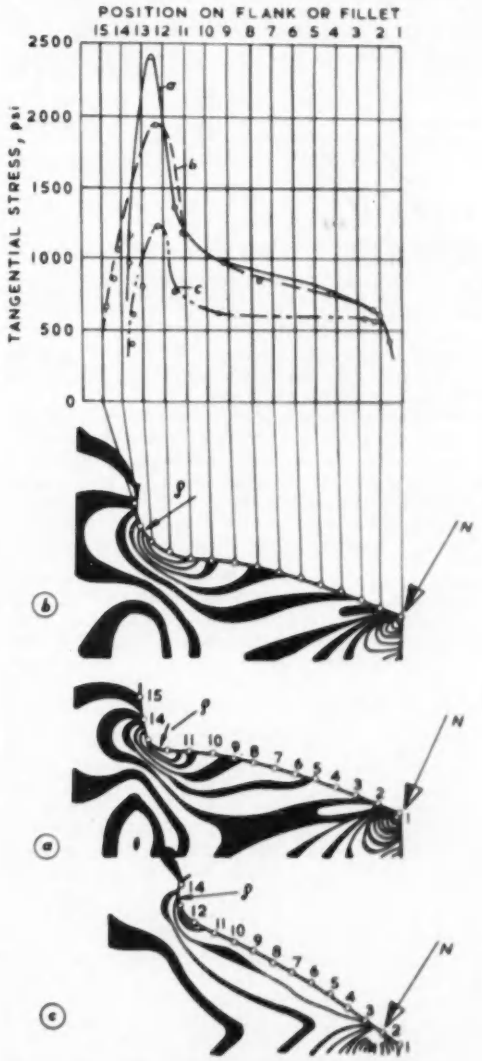

Fig. 3. Stress distribution along the flank and fillet, and photoelastic fringe patterns of three teeth of different profiles, with a tooth load N.
(*a*) 20-deg. involute tooth with fillet radius $\rho/m = 0{\cdot}2$.
(*b*) 20-deg. involute tooth with circular root ($\rho/m = 0{\cdot}5$).
(*c*) 30-deg. involute tooth with circular root ($\rho/m = 0{\cdot}27$).

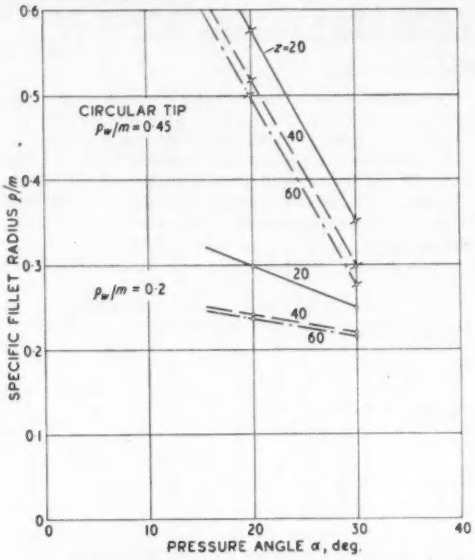

Fig. 4. **Specific root fillet radius ρ/m generated in spur gears with different pressure angles α and different numbers of teeth z by rack-type cutters with a specific tip radius $\rho_w/m = 0{\cdot}2$ or with a circular tip ($\rho_w/m = 0{\cdot}45$).**

unhardened gears the differences are less. Experience with gears in service also tends to show somewhat smaller differences than those noted here.

On generated gears or gears milled with profile cutters, the transition from flank to fillet is continuous. However, if, for instance, the hardened gear flanks are ground, a smooth transition is difficult to obtain and leads to wear and frequent re-dressing of the grinding wheel, unless the teeth are undercut or the fillet is specially machined to allow free grinding of the flank. Such a specially

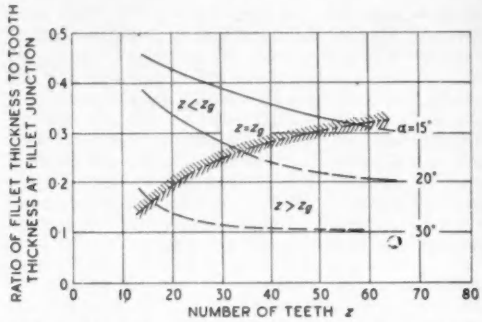

Fig. 6. **Theoretical magnitude of maximum fillet radius for circular roots of "uncorrected" gears with different pressure angles α and different numbers of teeth z.**
z_g = critical number of teeth at limit of undercutting.

machined fillet is expensive and slightly reduces the tooth thickness at the fillet but, as shown in Table I, a small landing or recess at the junction of a fillet left as-hardened with a subsequently ground flank does not reduce fatigue strength. Other tests, not yet published, have confirmed this fact, so that there is no need to fear a reduction in fatigue strength caused by such a discontinuity of profile. In the author's experience the discontinuity is dangerous only if it is due to hardening distortion, as may occur with very large gears.

Maximum Root-Fillet Radius and Profile Modification

Assuming that it is desirable to use the largest possible fillet radius, i.e., that of a circular root, this radius still remains to be determined under the geometrical limitations imposed by the pressure angle and the number and profile modification of the teeth, if these are assumed to have the usual standard working depth of $2m = 2/P$. Fig. 6 gives the result of a theoretical analysis of these limitations for "uncorrected" gears and, although in practice the values in Fig. 6 must be slightly increased, owing to the effect illustrated in Fig. 4, it can be seen that any increase in the pressure angle α must seriously reduce the largest fillet radius which can be accommodated—an important consideration where profile modification increases the value of α. Fig. 7 shows the theoretical limitations of the fillet radius for various relative profile modifications used with a constant pressure angle $\alpha = 20$ deg.; positive corrections x, i.e., thicker tooth roots, obviously permit only smaller maximum fillet radii. Hence, this point of view requires for maximum tooth

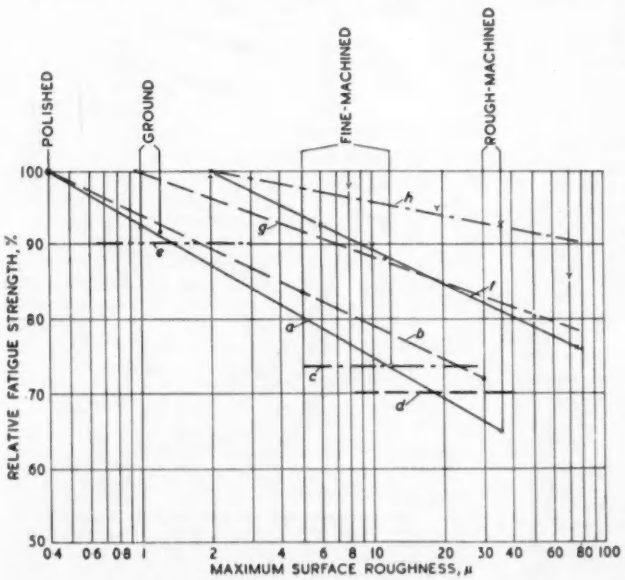

Fig. 5. **Influence of surface roughness on the relative bending fatigue strength of straight circular bars and gear teeth, according to various investigators.**

(*a*) Hardened and tempered 62-tsi Cr-Mo steel bar.[3]
(*b*) Unhardened 48-tsi 0·6% C steel bar.[3]
(*c*) Case-hardened Cr-Mn steel gear tooth.[1]
(*d*) Case-hardened Cr-Mn steel gear tooth.[2]
(*e*) Case-hardened Cr-Mn steel gear tooth.[3]
(*f*) Hardened and tempered 88-tsi Si steel bar.[4]
(*g*) Hardened and tempered 64-tsi Cr-Mn steel bar[4].
(*h*) Annealed 37-tsi 0·45% C steel bar.[4]

bending fatigue strength a compromise between desirable values of x and ρ_{max} or of α and ρ_{max}, bearing in mind the thickness of the tooth at the junction with the fillet.

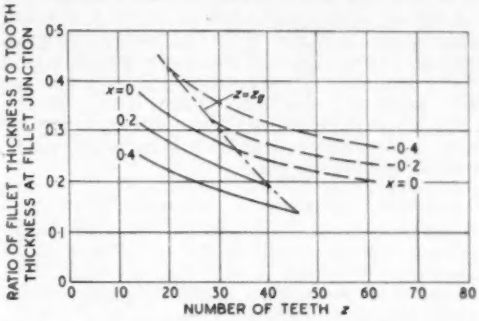

Fig. 7. Theoretical magnitude of maximum fillet radius for circular roots of differently " corrected " gears, with a 20-deg. pressure angle.
z_g = critical number of teeth at limit of undercutting.
x = Corrective displacement (positive, outwards) of mesh circle from pitch circle, in a gear of unit diametral pitch.

On the other hand, larger pressure angles, although unfavourable from the points of view of Fig. 4 and Fig. 6, have an advantage in providing not only a greater tooth thickness but also a more inclined tangent at the junction of flank and fillet. This tangent angle also influences the fatigue strength appreciably[5]. Fig. 3 gives an example. Thus, a comparison of *a* and *b* shows the influence of the root fillet radius. The fillet radius of *c* is only slightly larger than that of *a*, but the stress peak in *c* is very much smaller, the reduction exceeding the value to be expected from the increase in tooth thickness alone.

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Materials for Rocket Engines

By R. C. Kopituk. (From *Metal Progress*, Vol. 73, No. 6, June 1958, pp. 79–84, 4 illustrations.)

When it is considered that extremely active fuels such as liquid anhydrous ammonia and hydrazine, with oxidizers such as liquid oxygen, red fuming nitric acid, and liquid fluorine, are used to drive many high-power rocket engines, and that temperatures up to 6500°F can be attained during the blast, it is obvious that the selection of appropriate materials for their construction gives rise to a number of difficult problems.

In the operation of a typical rocket engine fuel flow is of special importance. The oxidizer and fuel are pumped into the mixing area, where they are ignited. The pump is operated by a turbine wheel, which is itself actuated by a gas generator powered through offshoots of the main fuel lines. There are thus several " hot " components in a rocket system, these being the turbine wheel, the gas generator, the injector head, and the combustion chamber, including the chamber extension cone. Representative temperature ranges are as follows :— Turbine wheel, 1200 to 1600°F; gas generator, 1900°F ; injector-head wall, 1000 to 1200°F ; combustion-chamber throat, 6500°F ; combustion-chamber side-wall (cooled), 1900°F ; gas at exit cone, 2500°F ; and uncooled wall of nozzle extension, 1800°F.

In choosing a material for any of these components, many factors, e.g., oxidation resistance, strength, workability, availability, and cost, must be taken into account. The conditions usually vary widely, but one factor common to most components is the duration of the operation. Because the total firing time is usually short, the main concern is with short-time properties, i.e., 10-hr rupture strength, 10-min yield strength, impact loading, and short-time fatigue strength.

Turbine Wheels

The turbine disc and blades in most rocket designs offer relatively few problems. Although they operate under extremely severe loading conditions and high thermal shock, they are not heated over the 1500 to 1600°F mark, because they are subjected to off-mixture combustion products from the gas generator. Furthermore, they operate for only short periods.

Gas Generators

The gas generator, in which, as already mentioned, the temperature of metal components usually does not exceed 1900°F, is of a cylindrical shape, closed at one end by fuel and oxidizer injectors, and open at the other for emission of the combustion gases. The gas generator is invariably made of thin welded sheet, and, if operated above 1600°F for a service life of less than 30 sec, an insulating ceramic coating may be used to realize the high strength potential of lower-temperature alloys. If the operating life is over 30 sec, the generator wall is usually not insulated, one reason being that the added weight of insulation needed to keep the temperature down would be excessive. Where non-protected metal is used, stainless steel is generally chosen, though low-alloy steels, and Inconel, among other materials, have been considered.

For longer running times, i.e., from 10 min to several hours, molybdenum alloys have been considered, but they have certain major disadvantages. For one thing, they become quite brittle when welded and, with the stresses and high vibrations of a rocket engine, this could prove disastrous. Furthermore, the ductility of the joints becomes worse below 60 to 120°F, and most engines are required to start satisfactorily at as low as —65°F. In rocket-engine systems, large pressure rises are quite often obtained in milliseconds, and the initial surge of pressure at this temperature would undoubtedly cause trouble in the welds. Recent work has improved ductility but, even so, far greater improvement is still required, while no really suitable coating has as yet been found for oxidation resistance.

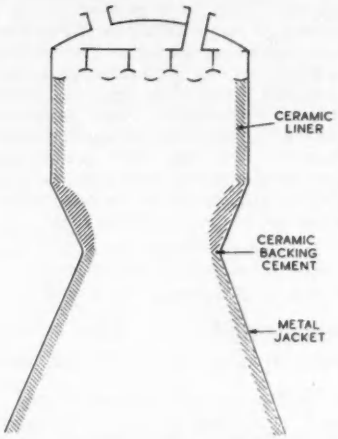

Fig. 1. Combustion chamber of an uncooled, non-regenerative type of rocket engine used for short-time firing.

Injector Heads

The injector head, which serves to inject the propellants into the combustion chamber, is usually in the form of a hemisphere or short cylinder, capped at one end and open to the thrust chamber at the other end. The injector head may be mechanically attached to the chamber by bolting, clamping, or welding, but it can also be an integral part of the thrust-chamber design. Good corrosion resistance and high strength are necessary in this item. Temperatures encountered are, for the most part, ambient, i.e., up to + 165°F (for fuels such as hydrocarbon mixtures, aniline, and butyl mercaptan), or down to — 290, — 320, or — 420°F for liquid oxygen, nitrogen, or hydrogen, respectively. The hot area faces the combustion chamber, and, although combustion occurs somewhat downstream of the injector and the latter is cooled by the propellants flowing through it, the severe turbulence of the gases can heat local hot spots to 2400 or 2500°F.

The injector head is usually of welded construction, sheet metals from 0·015 to 0·125 in. thick being employed. Several factors must be considered in selecting the materials. High strength is required for the outer case, and oxidation resistance is needed in the injector face. Also necessary is resistance to the corrosive propellants passing through the head and to the moderately high temperatures on the inside surface of the injector face wall.

The corrosion problem is not too serious, when most of the common fuels and some oxidizers are considered. However, with some of the more active propellants, such as white fuming nitric acid, red fuming nitric acid-HF inhibitor, liquid fluorine, or 90% hydrogen peroxide, conditions become more severe. Since the fuels and oxidizers are highly reactive, they must be separated from one another by leak-tight partitions in the injector. One method used to seal weld beads is to coat them with an acrylic slurry of a high-temperature nickel brazing alloy, and then to fuse at a higher-than-normal flow temperature (for pinhole penetration) in a suitable atmosphere furnace. Where a casting is not feasible because of design complexity, the materials must be readily formable, and suitable for welding or brazing. After fabrication is complete, it is often necessary to heat-treat (by precipitation hardening or air hardening) to minimize warpage in the assembly. By carefully examining corrosion time, temperature, and fabrication parameters, several material combinations can fit a specific application. Materials vary considerably, depending on the propellant combination, length of running time, number of firing cycles, strength requirements, and other factors. Such materials range from the low-alloy steels, through the 300 stainless-steel series, to the super-alloys such as A 286 and Inconel " X ". Insulating ceramic coatings, such as alumina and zirconia, are also used on the injector face. Corrosion resistance, strength, and fabricability are generally the prime factors to be considered when recommending materials for this component.

Combustion Chambers

Actually, the complete combustion chamber consists of three major parts, i.e., (1) the injector head, which closes one end, (2) the extension cone, which is open at the other end, and (3) the combustion chamber, which is located between (1) and (2),

The combustion-chamber extension cone is usually a truncated cone, welded or mechanically attached to the end of the combustion chamber. Its function is to develop more thrust from the expanding gases spurting from the combustion chamber, and it becomes more efficient at higher altitudes. This component is generally uncooled and is usually made of welded sheet. Though the temperature of the expanding gases decreases considerably and pressure is a minor consideration, the gases are still quite hot (around 1600°F) and tend to form stagnation or turbulence patterns, causing local hot spots reaching 2200 to 2500°F. When the combustion gases are highly oxidizing, " burning " of the metal occurs. Furthermore, the gases are moving at a high speed, so that erosion, particularly where it concerns the hot spots, is an important factor. Many sheet materials, from mild steel to the high alloys, have been evaluated, together with various metal, cermet, and ceramic protective coatings. The success of these materials and coatings depends in part on the injector design, which in turn affects the gas pattern. The corrosive characteristics of the gases also have an influence. Fabricability, and erosion and corrosion resistance are the major factors to consider when recommending a material for the extension cone.

The combustion chamber proper is cylindrically shaped, with a necked-down section (usually referred to as the nozzle or throat area) about two-thirds of the distance from the injector face. Propellants enter the cylindrical portion, where they mix and react in what might be termed a continuous explosion. Since one end of the chamber is closed by the injector head, the gases squeeze through the relatively narrow throat opening on the other end, picking up speed in the process and expanding out past the divergent section of the throat and the extension cone.

The combustion chamber is generally exposed to all the conditions to which the other " hot " components are exposed, but more so. Temperatures are high, and erosion is extremely severe. Both oxidizer and fuel can be corrosive. Fabrication can be quite complicated, depending on the design, and high strength with light weight is almost always a requisite. The combustion chamber thus presents some complex problems.

Basically there are two types of liquid propellant rocket chambers, i.e., the uncooled, for short-time firing, and the regeneratively cooled, for extended or repeated use. The uncooled chamber (Fig. 1) is usually ceramic-lined. Metals used have ranged from the low-alloy steels to the more highly alloyed materials such as the 300-

series stainless-steels, A 286 and super-alloys and Inconel "X". Titanium has also been considered. Low-alloy steels and titanium are used for their high strength-to-weight ratio where the final metal temperature will not be much above 1000°F. Reduction of critical materials is, of course, another attraction of the low-alloy steels.

Flanges are made from bar stock or forgings, while the outer shell is of welded sheet, spun or press-formed to shape. Welding is usually performed by the tungsten-arc gas-shielded method. All processing is critical, since the smallest leak cannot be tolerated in the chamber wall ; otherwise, a hole several inches in diameter will form in a few seconds of operation.

The part, after welding, is heat-treated and coated for corrosion and oxidation resistance. Sometimes, as in high-temperature nickel-alloy brazing or aluminium dipping, the coating process is part of the heat treatment. Where corrosion occurs in the uncooled chambers, aluminium dipping without subsequent diffusion, or electroless nickel plating, is quite satisfactory. If some oxidation and erosion resistance are also needed, as in the uncooled extension cone, a high-temperature nickel-braze coating, generally about 0·010 in. thick, is desirable.

Ceramic materials are almost always used for the uncooled thrust-chamber lining to maintain low metal temperatures. Although there has been considerable work on ceramics of late, much work is still required to improve the old ceramics and to develop new ones. There are basically two ceramic classes, i.e., the insulating type and the oxidation-resistance type. Typical of the former are the ceramic bodies, ceramic bonding cements, and some coatings such as alumina and zirconia. Typical of the latter are high-temperature enamels.

Insulating ceramic coatings are not used too frequently on uncooled liquid-propellant chambers, except for runs of very short duration. However, they are frequently applied to the extension cones ; oxidation resistant coatings may also be used.

Ceramic bodies and bonding cements are widely used for the lining. One of the big problems in fabricating uncooled chambers is the bonding and supporting of the ceramic bodies to the metal shell. Ceramic bonding materials should be readily pourable as-mixed and should give good bonding strength as-set. Furthermore, they must be able to withstand high vibration during operation and be resistant to the highly corrosive fuels. Some of the more common bonding cements are lumnite (calcium aluminate), foamed lumnite, lumnite and flint, plaster-of-paris, and alumina-base cermets.

Ceramic bodies used in liners and nozzles must have good refractory properties, and good oxidation, corrosion, erosion, and thermal-shock resistance. In addition, they must be capable of being readily moulded or machined into the shapes required. Designs make use of compressive strength of ceramic materials and are such that they are usually supported in tension by the outer metal shell. Some materials used are graphite, silicon-carbide-coated graphite, carbon-bonded silicon carbide, silicon-nitride-bonded silicon carbide, and silicon carbide with a recrystallized silicon carbide bond. Even plaster-of-paris bonded with glue has been used in short-duration firings.

In a regeneratively cooled thrust chamber (Fig. 2), the fuel or oxidizer passes between the outer jacket and the inner liner to cool the sidewall of the chamber. Combustion temperatures can reach 6500°F, while gas velocities can attain 8000 fps and over in the divergent cone. A unit of this type generally has to run repeatedly, the length of time for a single run usually being from 4 to 6 min, with a total operating life of several hours.

The chamber is usually of sheet-metal and tubing construction. Wall thickness generally does not exceed 0·125 in. and can be as low as 0·010 in. Where wall thickness is low, wire or glass-fibre wrapping is used for supports on the outside diameter of the chamber.

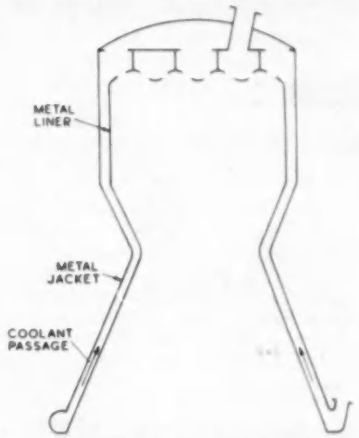

Fig. 2. **Regeneratively cooled combustion chamber.**

From the point of view of corrosion, the materials of welded construction contact such highly corrosive or reactive propellants as white fuming nitric acid, 90% hydrogen peroxide, hydrazine, and liquid anhydrous ammonia, to mention a few. Operation must be repeated many times, and there is always the possibility that the materials will be subjected to dilute concentrations of propellant in blind holes or cavities. They must also resist the highly corrosive products of combustion on the gas side, so that, coupled with the high erosion and high temperatures encountered on the gas side, the use of highly compatible materials with good oxidation, corrosion, and erosion resistance is essential.

Microscopic examination of various stages of metal oxidation failure in the throat area has revealed that, at temperatures above 1700°F, microscopic sections of oxide film are torn from the base metal by the highly erosive gases. A tiny, sharp edge remains, where microscopic gas turbulence occurs, giving higher local temperatures, with accelerated oxide formation and removal, while the wall thins, leading to higher propellant temperatures. A drop in cooling efficiency by the propellant occurs, further increasing wall temperature. Finally, as severe nucleate boiling of the propellant occurs, the metal-wall temperature rises rapidly and burns through. If base metals are already oxidation-resistant, and if design changes cannot improve cooling, the metal must be protected by a ceramic coating.

Some of the materials used for chamber liners have been the 300-series stainless steels, super-alloy A 286, Inconel, Inconel "X", nickel, and some cast and wrought aluminium alloys. Where the lower-melting or less oxidation-resistant materials are used, the oxidation-resistant or insulating coatings are employed, some of these including the Ni-Si-Cr-B alloys. Insulation-type coatings include alumina and zirconia. As powders, these can rapidly be sprayed to a given thickness, but have the disadvantage of poor erosion resistance.

The rod forms of alumina and zirconia are sprayed

on grit or sand-blasted surfaces by the oxyacetylene-flame spray gun, the molten particles adhering to the roughened surface. These coatings have good insulating properties and excellent erosion resistance, though adherence and sealing still need improvement. A precoat of sprayed Nichrome powder helps to some extent. It is hoped that, in the near future, through the use of composite metal-ceramic coatings, a molecular bond can be established. Also, the rod forms of alumina and zirconia coatings, as deposited, are 10 to 15% porous, requiring a highly oxidation-resistant base or precoating to prevent rapid oxidation of the base metal and subsequent flaking of the ceramic coating at the ceramic-to-metal interface. Owing to the low rate of application with this process, two to four guns are needed to complete one part in a reasonable length of time.

SWEDEN

Deformation Structures of and Splinters from Hand Tools

By A. HULTGREN. (From *Jernkontorets Annaler*, Vol. 142, No. 5, 1958, pp. 229–245, 29 illustrations.)

As the result of a number of eye injuries occasioned by small splinters or flakes of steel, necessitating their removal by surgery, the author has conducted an investigation into the microstructure of the steels concerned in such accidents, most of which occurred when a hand hammer was struck against a chisel or against a ploughshare during reshaping operations by forging.

A few used tools concerned in such accidents, including two hammers and a chisel, were also examined. No chemical analyses were made, but it can be assumed that the material in all specimens was of 0·5 to 0·9% carbon steel. All photomicrographs were made under oblique illumination, with the incident light coming from the left.

HAMMERS AND CHISELS

Examinations of one hammer, which had caused an eye injury from a splinter when driving a ploughshare into its seat, showed that the hammer face, 32 mm in diameter, had a very uneven surface, with numerous oblong dents, wrinkles, and, at the edge, scars from detached splinters. The surface was slightly polished, most of the relief being preserved, and etched in 1% nital. Fig. 1 is a photomicrograph of part of the hammer face, and shows, in addition to wrinkling, a crack. Fig. 2 shows how the edge of a thin layer, with cracks, has detached itself from the matrix. At higher magnifications (× 2000), it was found that the light areas, such as those in Fig. 1, were by no means smooth, but actually displayed a fine-point relief. In some cases, it was noted that, with the oblique illumination used, the points were raised, whereas, in other cases, they consisted of shallow depressions. This inconsistency has not yet been explained.

The wrinkled areas probably resulted from oblique blows, the hammer slipping in the direction of wrinkling. As a result of heavy and sudden plastic deformation, the contacting areas of hammer and ploughshare were heated beyond the Ac_1-point and were possibly welded together. The wrinkled light areas would then represent portions which had been deformed and possibly welded together, and the smooth light areas the adjoining portions of the matrix, which, without being plastically deformed, had been heated by conduction sufficiently for transformation. The cracks appearing in various locations indicate high thermal and transformation stresses.

In the face of this particular hammer, isolated narrow light bands were also noted, one of which (Fig. 3) formed a closed loop. Higher magnification established that these bands also had a point-relief structure, and, in addition, contained a central groove, here and there interrupted, as shown in Fig. 4, or containing cavities. It is suggested that the central groove represents a thin layer which was plastically sheared under the influence of a single blow received by a limited (perhaps protruding) portion of the uneven surface. The heat evolved in shearing, in terms of unit area, was sufficient for transforming the adjoining layers as well, so as to form what appears as one rehardened band with central markings. The composite band had a thickness of the order of 5 to 10 microns, and the central groove a thickness of 0·5 micron. The cavities noted in some cases may have been formed by shearing, or possibly later by corrosion.

Fig. 1. Section of the face of a hammer, showing wrinkling and cracking. (×65)

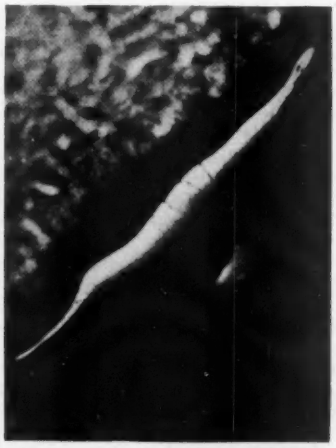

Fig. 2. Partly detached layer, with cracks, from the hammer in Fig. 1. (×125)

Vickers microhardness values were determined for the martensitic matrix and for the rehardened wrinkled areas, the results being as follows :— Matrix, 859 (with a 50-gram load), 842 (with a 100-gm load) ; rehardened areas, 821 to 934 (50-gm load), 734 to 893 (100-gm load). The considerable scatter obtained in the measured values of microhardness for the rehardened areas may have been due to varying

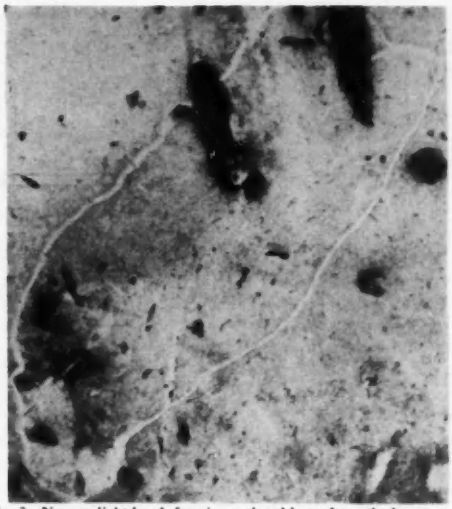

Fig. 3. Narrow light band, forming a closed loop, from the hammer in Fig. 1. (×110)

degrees of tempering or to insufficient thickness of the layer at some of the points tested.

Examination of another hammer, in this case with a wedge-shaped face, from which a splinter had been detached, was also made. The structure of this part of the hammer face is shown in Fig. 5. The surface shows various dents, rehardened areas, and irregular cracks.

A longitudinal section of the head of a hand chisel which had suffered a considerable amount of abuse by hammer blows is shown in Fig. 6. The polished section, after etching in Stead's reagent, shows the primary or fibre structure. The end portion is heavily upset and has spread out accordingly. Splinters had occasionally been sheared off the edge, thus allowing the remaining portion to spread out still further. Such deformation could be possible only because the head had not been hardened.

Examination of Splinters

To facilitate preparation, all splinters were embedded in bakelite, a section being polished and etched in nital for microscopic examination. The sections thus prepared had no definite relation to the actual irregular shape of the splinters.

A section of the splinter caused by hammering the ploughshare into its seat, as already mentioned, is shown in Fig. 7. The matrix is of tempered martensite, and narrow rehardened bands traverse one corner, one band following the edge and possibly representing the surface along which the splinter was sheared off. The presence of long and thin sulphide inclusions may be an indication that the splinter came from the ploughshare.

Part of a section of another splinter produced when using a hammer to refit a ploughshare is shown in Fig. 8. Several light bands, some narrow and some wide, can be seen in the matrix, which consisted mainly of tempered martensite. Longitudinal cracks in the thin bands were also present, these being particularly apparent at a higher magnification (Fig. 9). Microscopic examination of this specimen under polarized light showed a laminated structure, from which it may be concluded that plastic deformation by upsetting had occurred. The narrow bands and the laminations intersect more or less at right angles, and the wide bands probably result from sectioning rehardened thin layers in their own plane. A band forming a closed loop, as already mentioned, was also found in this specimen.

Islands of troostite or pearlite were present in this specimen and are a sign of insufficient rate of cooling during hardening. It was also noticed that the light bands tended to narrow when passing such an island. Two explanations of this phenomenon seem possible, i.e., (1) less heat was consumed in shearing pearlite then martensite, owing to lower shearing stress, or (2) the pearlite required a higher temperature for transformation to austenite. An interrupted central groove, similar to that shown in Fig. 4, was also observed in this splinter. It is believed that the large number of light bands in this splinter indicate that it came from the hammer, since a reforged ploughshare should be free from such bands. The hammer itself was not, however, investigated.

The third splinter examined was produced by a hammer blow against a chisel, and the structure of the matrix indicated that the steel had probably been har-

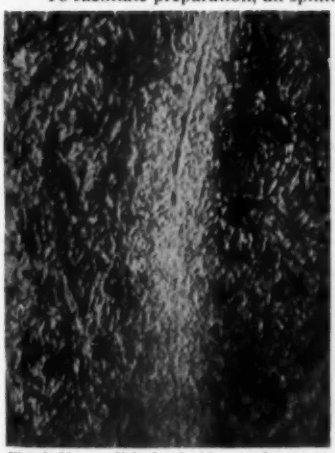

Fig. 4. Narrow light band with central grooves, from the hammer in Fig. 1. (×675)

Fig. 5. Structure of part of a wedge-shaped hammer face, from which a splinter had been detached, showing dents and cracks in the matrix. (×125)

Fig. 6. Longitudinal section, after primary etching, of an unhardened chisel head, showing heavy upsetting and shear fracture. (×5)

Fig. 7. Section of a splinter produced by a hammer blow against a ploughshare. (×110)

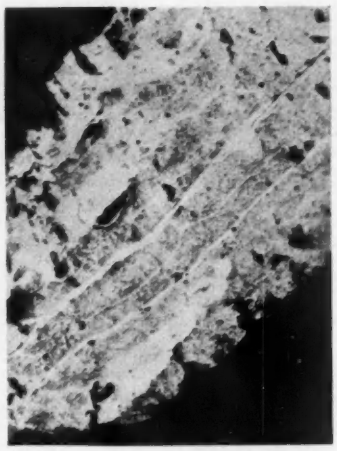

Fig. 8. Section of a splinter, probably from the edge of a hammer face, showing light bands in tempered martensite. (×125)

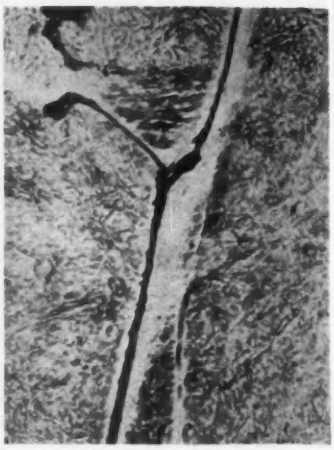

Fig. 9. Detail from Fig. 8, showing cracks in light bands. (×1000)

dened and then tempered at a rather high temperature, as evinced by the presence of numerous cementite particles. One end of an etched section from this splinter is shown in Fig. 10, in which the laminated character of the

Fig. 10. Section of a splinter produced by a hammer blow against a chisel, showing upset structure, with light band, stepped edge, and cracks. (×85)

structure can be discerned. This laminated structure, which was caused by upsetting, was more clearly shown in photomicrographs under polarized light. A rehardened short band, with a longitudinal crack, enters at the top edge and traverses the laminations, and a number of cracks follow the laminations, to the right and to the left, some of these cracks coinciding with steps in the contour of the right-hand edge of the specimen. It would appear that this stepped edge represents a formerly continuous shear surface from an earlier detachment of a splinter, the remaining portions then receiving further hammer blows which caused lateral cracks, localized spreading at the cracks, and finally detachment of the splinter under examination. It should also be mentioned that examination of part of the other end of the section of the splinter showed that it was traversed by closely spaced wavy thin bands, possibly an effect of only moderate hardness. It is believed that this splinter came from the chisel head.

Although the present investigation is based on a limited number of specimens and therefore permits only tentative conclusions, the observations made appear to suggest certain possible modes of deformation in steel subjected to impact, particularly in hardened steel, and to indicate in a general way how splintering may occur in hand tools.

A Thermionic Energy Converter using Caesium Vapour

(*Concluded from page 335*)

against cathode work function ΦC, with cathode temperature T as a parameter, and assuming that the value of the anode work function Φ_A is 1·8 V and that the radiating cathode area is the same as that of the electron-emitting cathode. From Fig. 7, it will be seen that, for each temperature, efficiency η has a maximum for a certain value of the cathode work function Φ_C. The temperature for which the efficiency curve has a maximum at $\Phi_C = 4{\cdot}52$ V is prohibitively high for tungsten. A cathode material having a lower work function than tungsten would allow operation at high efficiencies and lower temperatures. Possible materials are thoriated tungsten or a dispenser type cathode (L-cathode).

The high temperature requirements of the converter using a tungsten cathode appear to limit its use to solar-energy applications. Temperatures up to 3000°K are readily available in solar furnaces using parabolic mirrors for energy concentration. Because a single converter tube has a high power-handling capability, the thermionic energy converter may compare favourably with conventional thermoelectric devices. For solar-energy applications the absorption coefficient of the cathode must be considered. The efficiencies used in this paper refer to actual power delivered to the cathode.

Applications of the converter to other power sources (heat from a flame or nuclear energy) will presumably require operations at much lower temperatures. This may require lower work functions both for the cathode and the anode.

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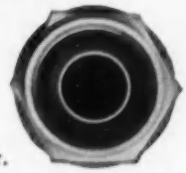

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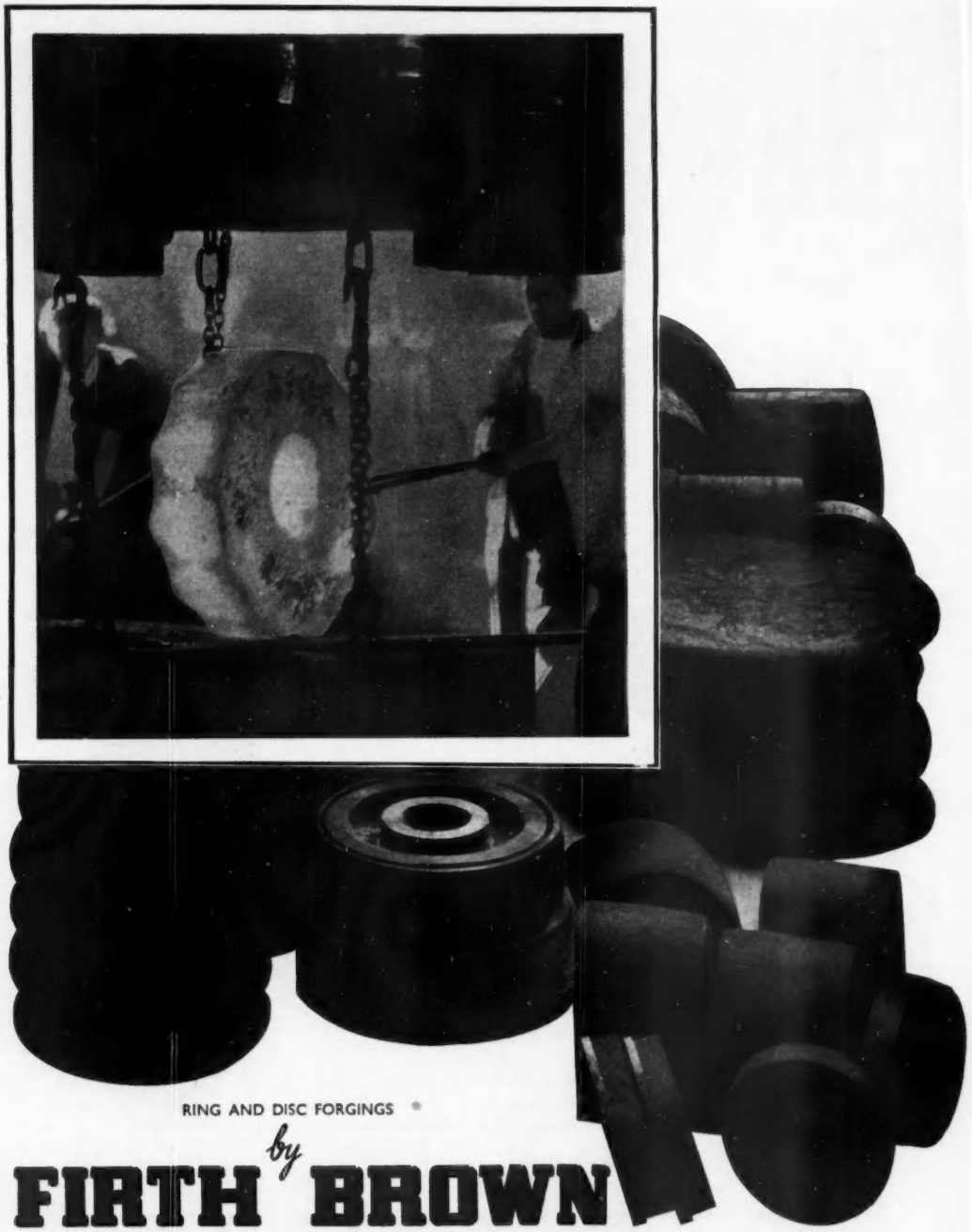

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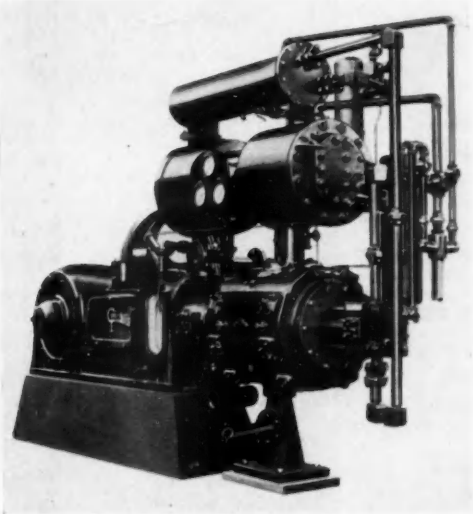
British Industrial Developments

Three-Stage Straight-Line Air Compressors

The new three-stage straight-line compressors, type TCP. 3, introduced by the Consolidated Pneumatic Tool Company, of London, S.W.6, are designed for the continuous compression of air or other gases to pressures of up to 1500 psi, with a corresponding free-air delivery of 242 cfm. For operating periods of not more than eight hours, the compressors may be run to give 238 cfm at 2000 psi.



In principle, the new TCB.3 compressor is a development of the class-T design, using a double-acting low-pressure stage followed by single-acting opposed second and third high-pressure stages. The frame carries a shaft supported on taper roller bearings, two sets of bearings being used to equalize end thrust. A wedge-adjusted connecting-rod of forked end construction transmits the drive to a solid box-type cross-head, which overtravels its guides by half its length, the cross-head face being ground to fit the bore of the guide exactly and being properly grooved for effective lubrication. A piston-rod connects the cross-head and the piston, while a stuffing-box with steel wipers located in the frame prevents oil from being carried out of the crankcase on the piston-rod. In the compression section, a double-acting first-stage piston interposed between the second- and third-stage pistons, acting in opposite directions, gives an almost equally divided load between forward and return strokes.

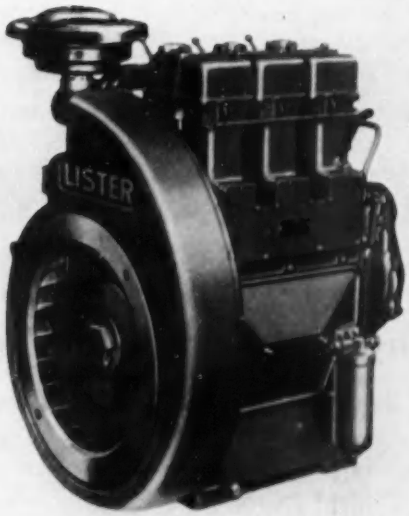
In operation, air is admitted at atmospheric pressure through Simplate valves to the two compression chambers formed on each side of the piston. Low-pressure air from the cylinder is then passed by further Simplate valves to multi-pass tubular intercoolers carried above the compressor. Water passes through the cooler in opposition to the direction of the air flow, the coldest water thus being in contact with the coolest air as it leaves. From the intercooler, air passes to the second-stage, single-acting cylinder, this cylinder being located at the crank end. From this cylinder it is further cooled in the second-stage multi-pass intercooler tubes before passing to the separator for removal of condensed moisture. The third-stage cylinder, of heat-treated forged steel at the outer end, completes the compression cycle.

A hollow, reinforced one-piece casting is used for the first- and second-stage piston, the third-stage piston comprising a hardened-steel self-aligning plunger. Lubrication of the cylinder is by a force-feed lubricator, with separate feeds to the first, second, and third stages. This force feed is positively driven from the cross-head, automatically supplying a visible, regulated quantity of oil to each cylinder. Metallic packings are fitted where the piston-rod passes through the second-stage cylinder-head. Substantial provision is made for water-jacketing, so as to provide much lower operating temperatures than are usually obtainable.

Air-Cooled Diesel Engines

Directly developed from the well-known Lister LD1 and LD2 engines, of 3½ and 7 hp respectively, two new air-cooled diesel engines, the type HA2 two-cylinder and the HA3 three-cylinder engine, with respective continuous power ratings of 20 and 30 hp at 1800 rpm, are announced by R. A. Lister & Co. Ltd., of Dursley. These air-cooled units form convenient and readily adaptable power units for a wide sphere of industrial, agricultural, and marine applications under all climatic and ambient-temperature conditions. The HA3 engine is illustrated.

Direct injection of the fuel is provided by an injector of patented design, in conjunction with a special combustion chamber in the piston crown. The nut securing the nozzle of the injector body is finned, and the body itself is heat-insulated from the cylinder head. The combustion chamber is of the open type and basically consists of four lobes, making a clover-leaf pattern in a bowl. With this design, extremely effective mixing of fuel and air is ensured, and, in conjunction with a compression ratio of 17:1, starting is easily achieved. Cooling is effected by means of a centrifugal fan bolted to the flywheel, the blades of the fan being specially designed to deliver an ample supply of air at the right pressure. Cooling air is



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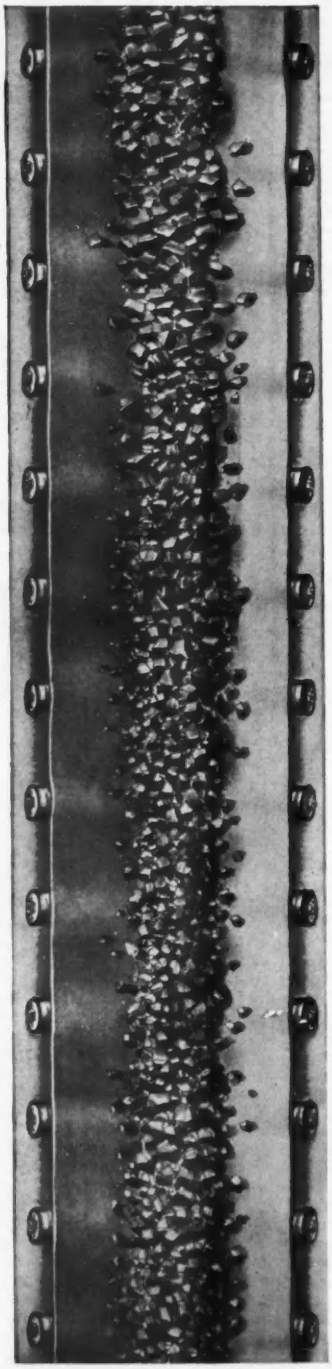

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trunked around the cylinder barrels and over the finned nut of the fuel injectors by baffles which maintain a constant flow of air to all parts of the engine.

In addition, so as to bridge the gap between the 3½ and 7 hp engines and the new 20 and 30 hp engines, Lister have introduced three other new air-cooled engines, these being types SL1, SL2, and SL3, with respective ratings at 1800 rpm of 4¼, 8½, and 12¾ hp. The basic difference between these new engines and the 3½ and 7 hp versions lies in the increased diameter of the piston and cylinder barrel, and the use of new connecting rods. However, although additional power has been obtained by increasing the cylinder bore, this has been achieved without any sacrifice in fuel economy at full load.

The "Mercast" Mercury-Pattern Method of Investment Casting

Formed approximately three years ago, Sankey-Telcon Limited, of Crawley, Sussex, a company jointly owned by Guest, Keen and Nettlefolds Ltd. and The Telegraph Construction and Maintenance Company Ltd., is the sole operating licensee of the "Mercast" process of investment casting outside the U.S.A., and has been operating on a production basis for about eighteen months.

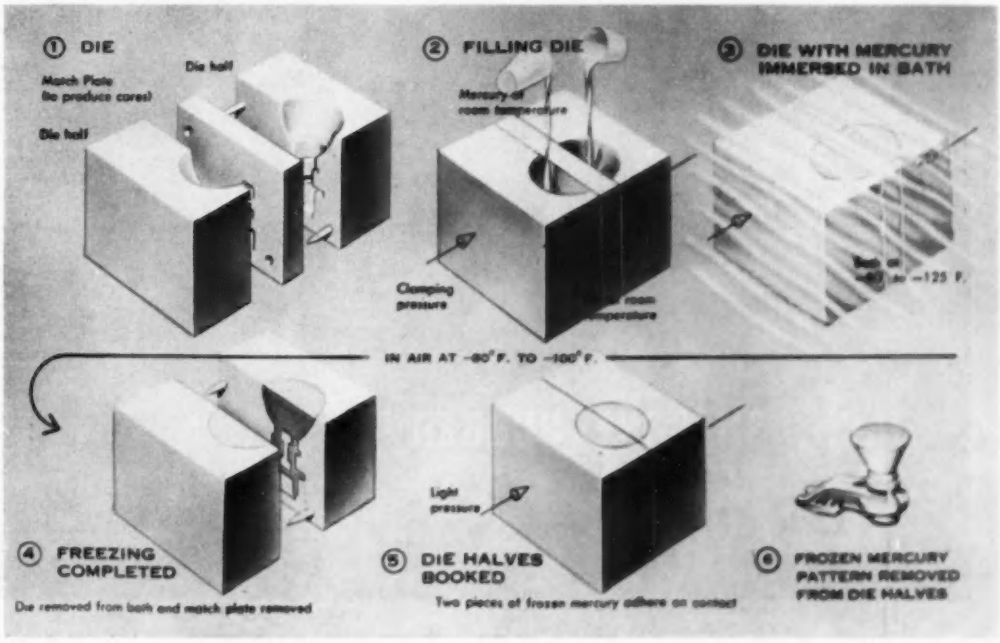
In the "Mercast" process of precision investment casting, frozen mercury is used as the pattern material and enables castings of better quality and greater accuracy than those from wax or plastic patterns to be produced. Among other advantages, mercury as the pattern material has a low solid/liquid expansion, so that thin shell moulds can be employed, without any risk of cracking the shell. Furthermore, it readily welds to itself under light pressure, so that accurate and intricate patterns can be produced by abutting or "booking" simple component patterns together in a precision jig. This characteristic also enables cores to be positioned in sites which would be inaccessible in other techniques, while the high density and good wetting characteristics of mercury permit reproduction of minute detail.

The use of a zircon-base refractory material, free from all combined or absorbed moisture, in conjunction with the mercury pattern, permits the production of a shell mould which, after firing, is strong, stable, and inert to most alloys. The shell mould, as against the block mould produced by other investment techniques, enables preferred metallurgical practice to be employed during casting, while freedom from porosity, shrinkage cavities, and blow-holes, and the development of controlled grain size and consistency of dimensions are all achieved. The particle size of the zircon-base refractory investment material is selected in relation to the metal being cast and permits the attainment of fine surface finish of the casting. In addition, the use of shell moulds enables chills to be used, allowing directional solidification to be induced, even in those cases where rapid changes in cross-section occur. The strength of the thin shell mould is sufficient to withstand the most severe mechanical shock associated with casting by suction, vibration, inversion, or by centrifugal or vacuum casting methods.

The mechanical properties attained by the "Mercast" process, the details of which are shown in the illustration, are better than those normally obtained by other casting techniques. Indeed, it is stated that, in the U.S.A., castings are in current production with an ultimate strength in excess of that obtainable from forged components.

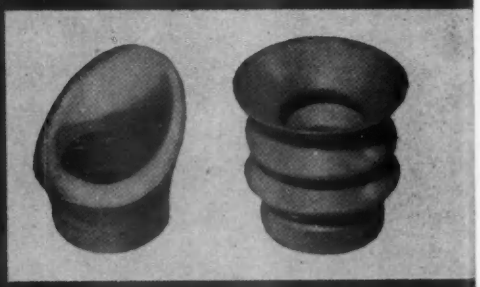
Synchronized Projection and Sound Equipment with Automatic Switching Control Pulse

Basically intended for use in conjunction with one of their film-strip or slide projector attachments, the new "TAP" (Tape Automatic Projection) system developed by Siramco Limited, of London, W.8, successfully solves the problem of controlled switching associated with a spoken commentary by utilizing a control pulse which can be used to operate a variety of projectors using film-strips or slides, automatically and reliably changing the picture at any predetermined moment in the commentary.


① DIE
Match Plate (to produce cores)
Die half
Die half
② FILLING DIE
Mercury at room temperature
Clamping pressure
③ DIE WITH MERCURY IMMERSED IN BATH
IN AIR AT −60° F. TO −100° F.
④ FREEZING COMPLETED
Die removed from bath and match plate removed
⑤ DIE HALVES BOOKED
Light pressure
Two pieces of frozen mercury adhere on contact
⑥ FROZEN MERCURY PATTERN REMOVED FROM DIE HALVES

I.C.I. Silicone Rubbers are worth looking into

Aircraft sextants and periscopes must operate perfectly at the low temperatures encountered in high-altitude flights. So even the flexible eyepieces of these instruments present a problem—for natural rubber becomes too rigid under these conditions. I.C.I. Silicone Rubbers, however, retain their flexibility—and many other desirable properties—over a very wide temperature range. In this case—they completely met the requirement for operation at −60° C. And they will meet other specifications, too, from 250° C to −80° C. If you have a problem within this range—electrical, chemical or mechanical—I.C.I. Silicone Rubbers are certainly worth looking into.



Periscope instrument for aircraft, manufactured by Taylor and Hobson Ltd., with eyepieces of I.C.I. Silicone Rubber moulded by Waltham Rubber and Plastics Ltd.

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In addition, if desired, the control pulse can be used to initiate any desired sequence of switching or other control functions, not only in connection with educational, training, or other displays, but also in connection with the control of a series of operations or a sequence of machines in a manufacturing process.

The " TAP " instrument fundamentally comprises a dual-channel tape-recording system, one channel being reserved entirely for speech or other intelligence, and the other for the generation of the control pulse. The pulse-generating and playback circuits are fed from a fully regulated power-supply rail, and the impulse oscillator and associated playback amplifier are accurately tuned, so that, while operation is assured over variations in tape speed of as much as $\pm 15\%$ of nominal speed, spurious pulsing caused by random noise or other disturbances is strongly inhibited. Moreover, the complete isolation of the intelligence and pulse channels further enhances security and reliability of operation.

As normally supplied, the impulse relay provides for a change-over function on each impulse, so that any external circuit may either be completed or opened, as well as switched from one path to another. Other, more complicated relays can, however, be supplied, as required. The process of recording is extremely simple. Thus, apart from the normal use of a microphone for speech recording, a button is pressed for approximately one second whenever a control pulse is required during playback. The relay response is within 40 millisec of the leading edge of the recorded pulse. The tape recorder incorporates the usual erasing facilities, so that recording and reproduction can be effected at any moment, and the commentary can be changed whenever necessary. In addition, continuous operation is easily achieved by the use of a special endless-loop cassette.

Treatment of Files with Colloidal Molybdenum Disulphide

According to tests carried out jointly by two Sheffield companies in the B.S.A. Group, William Jessop & Sons Ltd. and J. J. Saville & Co. Ltd., treatment of files with a dispersion of colloidal molybdenum disulphide can improve their cutting efficiency by as much as 60%.

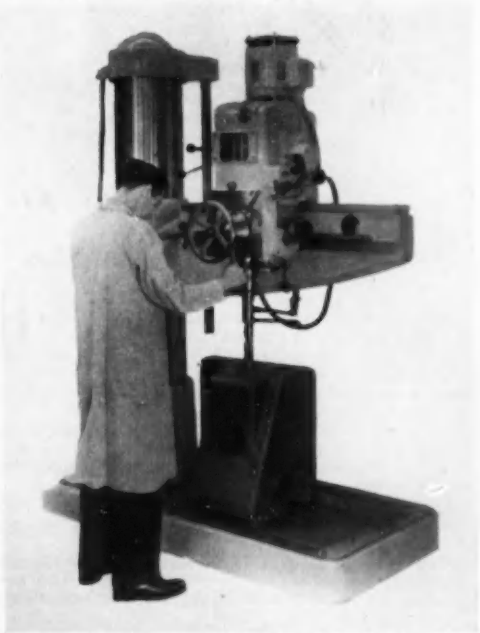
In the initial tests, one batch of 12-in. hand bastard files were spray-coated with " dag " product 1127 (colloidal molybdenum disulphide in alcohol), and others with " dag " product 1209 (colloidal molybdenum disulphide in toluene), both these products being prepared by Achesons Colloids Limited, of London, S.W.1. In all these tests, both products were diluted with toluene to a suitable spraying consistency. It should be appreciated that, after cutting the teeth of a file, it is hardened by heating and then quenching in brine, and, because the file must be hard as possible, no tempering treatment can be carried out. For this reason, it was not possible to heat-cure the coating formed from product 1209, and files treated with this material showed no improvement. Consequently, product 1127, which requires no subsequent heat-curing treatment, was used in the tests which followed.

Encouraging results were obtained when the files treated with product 1127 were tested on a file-testing machine, in which each file face was rubbed 30,000 times on a steel bar under a constant pressure, the amount of steel removed from the bar being a measure of the performance of the file. To confirm these favourable results with 12-in. hand bastard files, further tests were carried out with 12-in. hand smooth files and 6-in. three-square engineers' files (triangular cross-section), each type having a finer cut than the 12-in. bastard files. Even better performance was obtained, an increase in efficiency of 50% with the smooth files and of 60% with the three-square files being noted.

The results revealed that the percentage improvement varied with the fineness of the teeth. This was attributed to the fact that the treated teeth did not clog as much as usual, the coating of product 1127 apparently acting as a kind of " parting agent " between the filings and the teeth. It is therefore believed that this treatment will be of particular value for smooth files, especially when used on difficult " clogging " metals. Another advantage of the treatment is the good appearance of the sprayed file. Furthermore, from preliminary tests, it seems that the protection against corrosion provided by the coating is not inferior to that offered by materials in current use.

Radial Drilling Machines

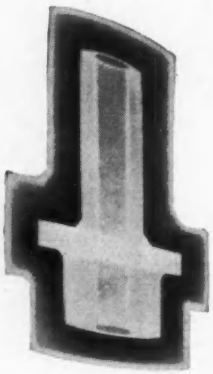
Many new features are incorporated in the new Kerry radial drilling machines, models E.3 and E.4, produced by Qualters & Smith Bros. Ltd., of Barnsley, one of the Kerry group of companies. The model E.3 machine is capable of drilling up to a radius of 46 in., enabling holes to be drilled 37 in. out from the base of the column. On the E.4 model, the radius of swing is 58 in., permitting holes to be drilled 49 in. out from the column. The maximum capacity of these machines is $1\frac{1}{2}$ in. diameter in steel and $1\frac{3}{4}$ in. diameter in cast iron.



The column, which is of massive proportions, consists of two members, an inner column securely bolted to the base of the machine, and an outer sleeve which revolves around the inner column on roller bearings. The inner column is ribbed internally to resist bending stresses. A clamp is provided at the bottom of the sleeve and, by finger-tip pressure, locks the sleeve securely to the inner column. As the clamping action is on a vertical plane, not only is it extremely positive, but there is no risk of the deflection often experienced with the earlier type of clamping mechanisms.

The arm is raised and lowered by means of an easily accessible lever which raises the arm when in the " up " position and lowers it when in the " down " position. When the lever is released it instantly returns to the centre position, when the arm is automatically locked. With this device it is not possible to raise or lower the arm without first unlocking the arm from the column, and it also ensures that locking is completed after movement of the arm on the column.

THE FOURTH DIMENSION



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Power-elevating and lowering are accomplished by a 1½-hp motor built into the back of the arm and driving a worm-wheel and nut, which revolve on a stationary screw. A safety nut is provided for guarding against the arm dropping, in the unlikely event of failure of the elevating nut. In addition to the safety nut, a safety clutch is provided on the top of the elevating screw, instantly stopping the functioning of the elevating mechanism, should the arm or head accidentally come into contact with anything whilst being raised or lowered.

The head moves freely along the arm on needle roller bearings and can be clamped securely in any position by a conveniently placed lever. All controls are grouped and accessible, ensuring rapid operation. A 3-hp reversing motor mounted directly over the head provides the drive to the gearbox. Nine spindle speeds are obtainable by levers conveniently placed on the left-hand side of the head. A constant-speed pump provides oil to the whole of the gearing. Quick hand traverse, fine hand feed, and three rates of power feed are provided. Power feed is engaged by moving a star handwheel axially. An automatic depth trip for stopping feed at any predetermined depth is provided. Power feeds are obtained by a selector mounted on the right-hand side of the head.

Polyvinyl Chloride Pastes

A range of polyvinyl chloride pastes, known as " Plastisols ", has been developed by Dunlop for a wide variety of industrial applications. Plastisols are basically dispersions of fine P.V.C. powder in a liquid plasticizer, and, under the influence of heat, gel and solidify to a rubbery solid without appreciable loss of volume. They are particularly suitable for casting hollow toys in heated metal moulds and for coating, by means of a hot-dipping technique, metal articles such as draining baskets, wire trays, and racks.

An important application is in the manufacture of cars, where the paste is painted between the open edges of spot-welded metal seams, setting and sealing the seam when the car goes through the baking oven. Other uses include the backing of textiles and tufted carpets and the manufacture of coated papers.

New Treatment for Residual Fuel Oils

A new treatment for residual fuel oils, low-viscosity fuels, distillates, and coal-tar fuel has been introduced by the Amber Chemical Co Ltd., of London, W.1. The treatment, in the form of a liquid additive known as " Amber SSR511 ", minimizes the formation of sludge by retarding the rate of oxidation occurring in stored fuels, and by dissolving the resins, asphaltenes, gums, and congealed residual oil which are the main constituents of sludge.

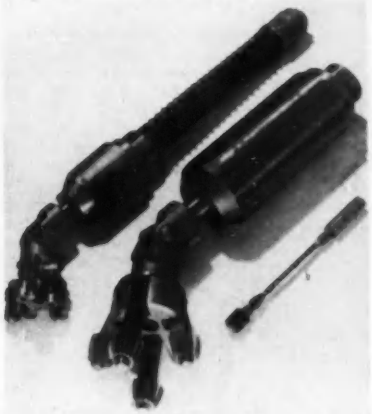
The formation of sludge is frequently an indirect result of modern refining techniques, which tend to remove a high proportion of the volatile fractions leaving the residual fuel correspondingly lower in quality. Some chemical reaction or oxidation of the fuel may occur in storage prior to combustion—a process which is increased by the application of heat and the presence of water. It may be accelerated by minute amounts of metallic compounds, such as copper (probably derived from the fuel system). The resulting oil insolubles, having a high carbon content, can seriously affect combustion and cause blockages, which may lead to repeated overhauls or to a complete stoppage.

Amber SSR511, which possesses a greater solvent power than the oil itself, will dissolve the greater part of this sediment before it reaches the burners and will inhibit the oxidation process in the fuel storage tank. The additive is completely soluble in the oil, and its action is not affected by the presence of water. It is non-corrosive and non-volatile, has a high flash-point, and is safe to store and handle.

Tube-Cleaning Equipment

The range of Lagonda tube-cleaning equipment which the Consolidated Pneumatic Tool Co. Ltd., of London, S.W.6, are now producing at their Aberdeen works, includes three sizes of vane-type motors operating a variety of cutting heads for dealing with straight or curved tubes from ½ in. to more than 6 in. i.d.

The smallest motors are those of the 600 series (shown at the bottom of the illustration), designed specifically for use with small straight tubes of from 0·495 to 1·820 in. i.d., and curved tubes of from 0·791 to 2·080 in. i.d. with a minimum radius of 6 in. The 600 series, comprising some eight models of motors, includes short- and long-bodied units which house the miniature vane-type air motors, the short motors being used for curved tubes and the long motors for straight tubes.



The 1300-series motor (top of illustration) has been produced for cleaning both straight and curved tubes of from 1⅞ to 3⅛ in. i.d. For larger tubes of over 4¼ in. i.d., sleeves are fitted over the motors. A force-feed oil-lubrication system, delivering oil under pressure to the bearings, is a particular feature which, together with a simple construction of the vane motor, keeps maintenance to a minimum. This series has a very wide application, apart from boiler-plant maintenance.

The 1100 series (centre of illustration) constitutes a range of heavy-duty motors for dealing with straight tubes only, from 2¼ to 6 in. i.d. In this motor, developed originally for refinery service, ball thrust bearings at both ends accommodate rotor drag caused by operator thrust when working a heavy deposit and prevent friction due to pulling of the self-feeding cutter heads, the bearings being lubricated by forced feed.

A very wide selection of cutter heads and brushes is available. All cutter heads are, however, variations of straight and trackless cone cutters in which the spacing of the cutter teeth or blades is so arranged that any one tooth does not return to the same point in a tube in successive revolutions of the head, thus preventing the formation of a tooth design in the tube and ensuring an even finish. For straight tubes, the cutter heads are directly coupled to the shaft of the motor, whilst, to obtain flexibility in curved tubes, a universal joint is always used between the cleaner motor and the cutter.

Apart from much straightforward general service, there are numerous specialized applications for this equipment. One instance is the removing of spent catalyst material from reactors and converters of the tubular type, using exhaust air to carry the recovered material up the tube and away past a deflector and dust seal to a container. Other specific uses include the cleaning of air preheaters which have become completely plugged with fly-ash.

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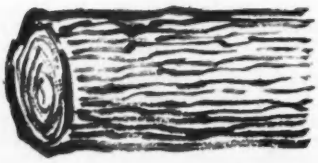


'Eclipse' hacksaw blades and other tools are made by James Neill & Co. (Sheffield) Ltd., and are obtainable from all tool distributors.

UH 27.

ADDITIONAL ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

Insulation Ageing in Pure Oxygen and in a Vacuum.

By L. C. WHITMAN. (From *Power Apparatus and Systems (A.I.E.E.), U.S.A.* No. 36, June 1958, pp. 294–298, 10 illustrations.)

OXIDATION and evaporation are two of the mechanisms by which insulation deterioration have been described. In most ageing tests, both of these processes are in action, with little data giving their relative importance. The tests described in this paper were therefore made with a view to showing their relative effects and also to studying the possibility of acceleration of these effects to give more rapid evaluation of various materials.

Representative insulations were thermally aged in pure oxygen and also in a moderately good vacuum. The resulting ageing rates were compared with similar specimens aged in air and in nitrogen. A 50% dielectric criterion was used in evaluating deterioration rates. The evaporation component of ageing was found to be minor, as compared with the oxidation component, for the materials tested, except for silicone-impregnated materials. Other conclusions derived from this investigation may be summed up as follows :—

(1) At 150°C, insulating ageing for some materials may be as much as fifteen times as rapid in pure oxygen as in air.

(2) Silicone materials do not appear to be appreciably affected by oxygen concentration in the gas medium, even when going to the extreme of pure oxygen.

(3) The vaporization component of insulation ageing for kraft paper and black varnished cloth is approximately doubled in reducing the gas-medium pressure from 5 psig to a vacuum of 29 in. Hg.

(4) For the cases tried, insulation life in a vacuum is about one half of its life in nitrogen and several times its life in air.

Factors Influencing the Stability of Piston-Type Control Valves.

By G. J. NOTON and D. E. TURNBULL. (From an advance copy of a paper received from *The Institution of Mechanical Engineers, London*, June 1958, 15 pages, 18 illustrations.)

THE tendency of certain piston-type valves to oscillate, when incorporated in hydraulic position-control systems, has been recognized for several years. It is known, for instance, that instability can be caused by oil-compressibility effects in a hydraulic position-control system using a spool valve with rectangular ports, and that resonance or " organ-pipe " effects in the connecting pipes of such systems can cause continuous oscillations.

In the past, instabilities have been traced to one or more of these causes, but very frequently systems have remained unstable, even when all apparent causes have been eliminated, and no explanation for this has been found. A further and very common cause of valve instability is given in this paper, together with some experimental results confirming its existence.

The reaction force on an open, spool-type, control valve acts in such a direction as to close the valve. For this reason a four-way valve, having its closed position at the centre of its stroke, can overshoot if the reaction force imparts sufficient energy to it during closure. If there is insufficient damping on the spool, a continuous oscillation may arise, and the present work investigates the dynamic behaviour of a common type of hydraulic position-control system in which such an oscillation has been found to occur.

Good agreement is obtained between the predicted and experimental minimum amplitudes and frequencies of oscillation and also between the theoretical and measured pressure fluctuations in the system. A graphical solution of the equation of motion of the system is included in the results and, with the aid of " Describing Functions ", the approximate dynamic behaviour of the system considered may be derived.

Graphical Method of Calculating Heat-Transfer, Condensation, and Vaporization Rates in Processes Involving Water-Steam-Air Mixtures.

By D. B. SPALDING. (From an advance copy of a paper received from *The Institution of Mechanical Engineers, London*, June 1958, 27 pages, 28 illustrations.)

THE requirement often arises for predicting heat-transfer, vaporization, and condensation rates in systems involving moist air and a free water surface. Methods of calculation are available in some cases, but these are either approximate (for example, limited to small temperature differences), or tedious, involving iteration.

This paper describes a graphical method of calculation, which may be considered as exact for engineering purposes, which is valid for all cases, and which only exceptionally involves iteration. The method requires a chart of enthalpy against composition for air-water mixtures, and appropriate lines drawn on this chart enable heat- and mass-transfer rates, and gas and liquid conditions to be read off.

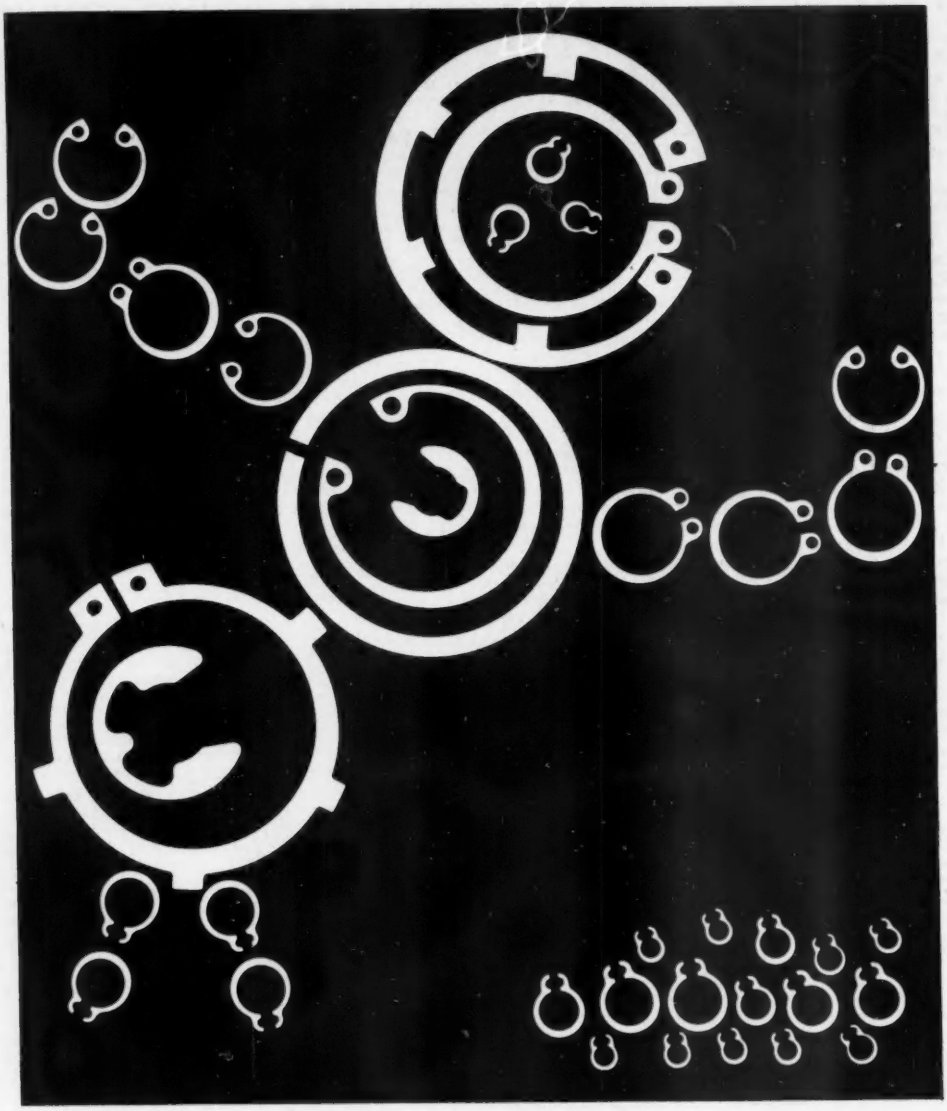
As shown in the paper, the properties of a plot of the isotherms and phase boundaries of water-steam-air mixtures on an enthalpy-composition diagram for constant total pressure permit graphical constructions, enabling surface conditions, heat- and mass-transfer rates, and equipment size to be deduced for convection, steam-drum, and radiant drying plant, cooling-towers, condensers, gas coolers, and trickle coolers. In addition to the chart for atmospheric-pressure calculations, data from which charts for other pressures may be simply calculated are also presented. The graphical method may also be applied to other systems involving phase changes.

The Welding of Chromium-Molybdenum-Vanadium Steels for High-Temperature Steam-Turbine Components.

By R. J. CHRISTOFFEL, R. M. CURRAN, F. H. DOMINA, and C. H. SOLDAN. (From *The Welding Journal, U.S.A.*, Vol. 37, No. 7, July 1958, pp. 295s–303s, 15 illustrations.)

ALTHOUGH a number of steam turbines built for operation at 1050°F originally utilized austenitic stainless steels for turbine piping and for valve and shell components, the vanadium-containing chromium-molybdenum steels have been employed almost exclusively in more recent years for the high-temperature components of such machines. In the case of the Cr-Mo-V base metals and weld metals, however, heat treatment and the resulting microstructure are of major importance in establishing high-temperature properties. Consequently, the welding of Cr-Mo-V steels for high-temperature service requires consideration of these factors, in addition to those involved in the fabrication of the conventional Cr-Mo steels.

This report summarizes the procedures, including preheat and post-weld heat treatments, which have been developed for welding Cr-Mo-V base metal with a ½% Cr/1% Mo electrode, using both the manual metal-arc and submerged-arc processes. The rupture strength of this weld metal, as well as that of other low-alloy-steel



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weld metals, has been evaluated and has been found to be less than that of the base metal. The effect of composition and heat treatment on the rupture strength of low-alloy-steel weld metals has also been evaluated.

In addition, a Cr-Mo-V manual metal-arc electrode has been developed and qualified for welding the Cr-Mo-V base metal. The rupture strength of weld deposits made with this electrode in the normalized-and-tempered condition is comparable with that of the base metal. This weld metal should not be used with a stress-relief heat treatment, as the full properties of the weld are not developed, and such a treatment can produce cracking.

An Electro-Hydraulic Speed and Load Control for Constant-Speed Air-Turbine Drives.

By P. DANTOWITZ and L. G. NORRIS. (From *Applications and Industry* (*A.I.E.E.*), *U.S.A.*, No. 36, May 1958, pp. 99–106, 11 illustrations.)

THE demand for high-quality constant-frequency power for aircraft electrical systems has been increasing rapidly over the past decade, but this demand has, in turn, placed increasingly stringent requirements on the electrical system and drive controls. In order to satisfy these requirements, an electro-hydraulic speed-control development programme was initiated, the choice of an electrical system being based on the following factors :—

(1) The greater immediate potential for higher accuracy of control, as demonstrated by an earlier breadboard-type mechanization.

(2) The significant improvements which have taken place in the reliability of electrical components and in methods of manufacture and packaging, to achieve physically rugged assemblies.

(3) The relative ease of handling intelligence, i.e., of adding and subtracting signals and of shaping frequency response characteristics.

(4) The ease of adjustment and modification during the development programme.

(5) The ease of instrumentation and measurement.

This paper presents a description and analysis of an electro-hydraulic speed and load division control for an aircraft constant-speed air-turbine drive for a 400-cps 60-kVA alternator. At present, this system is undergoing flight and qualification testing, and representative performance data, in the form of test results, are presented.

The results of this programme indicate that a much higher level of performance can be obtained for the same or less development effort with an electro-hydraulic control than with a mechanical-hydraulic system. In addition, it was found that the approach of using an analogue computer as an operating control to investigate various approaches and system tolerance limits early in the programme was of considerable advantage, while the electrical approach permitted greater ease and speed of evaluating the prototype system, once it had been mechanized.

Theoretical Assessment of the Performance Characteristics of Inward Radial-Flow Turbines.

By F. J. WALLACE. (From an advance copy of a paper received from *The Institution of Mechanical Engineers, London*, August 1958, 14 pages, 11 illustrations.)

THE theoretical assessment of flow at the design point, in the simplest case, is based on isentropic flow, both in the nozzle and rotor passages, while the torque and hence the power developed in the rotor are derived from moment of momentum considerations. This simple treatment provides useful results with an accuracy of $\pm 10\%$, depending on the particular quantity considered, and from it the influence of changes in such quantities as diameter ratio, nozzle exit angle, degree of reaction, radial velocity ratio, and overall pressure ratio on performance at the design point may readily be determined.

While the simple centrifugal compressor has been widely used over a considerable period of time and in a variety of applications, particularly in aircraft gas turbines and aero-engine superchargers, and its behaviour is therefore reasonably well understood, the inward radial-flow gas turbine has only recently begun to attract attention. As a result, its characteristics are not understood as fully as those of the centrifugal compressor. Inward radial-flow turbines have a number of attractive features, such as robustness, cheapness, and relative immunity from thermal stresses, which render them particularly suitable, where the mass throughput and overall pressure ratio are moderate.

While the assessment of performance and flow conditions at the design point presents no very great difficulties, the evaluation of performance under conditions of reduced speed and pressure ratio, a knowledge of which is essential in most applications, does not appear to have been attempted hitherto. As a result, an analytical treatment of part-load conditions is outlined in this paper. In addition, the influence of the various design parameters on the overall characteristics is examined, and tentative suggestions are made for the best combination of these parameters for particular applications. It is not suggested, however, that the numerical results obtained with the aid of these treatments are sufficiently accurate to obviate the need for careful experimentation, the degree of accuracy of the treatment being clearly limited by neglect of frictional, as distinct from shock, effects. On the other hand, it is felt that purely theoretical assessments of frictional effects are almost invariably in error and that, in the absence of comprehensive experimental data, it would be misleading to incorporate frictional-correction terms in the theoretical equations. The present work is intended rather to convey a clear physical picture of the flow mechanism in the radial inward-flow turbine.

The Relation between Current and Field during Anodic Oxidation.

By P. WINKEL, C. A. PISTORIUS, and W. CH. VAN GEEL. (From *Philips Research Reports, Holland*, Vol. 13, No. 3, June 1958, pp. 277–295, 11 illustrations.)

WHEN metals like aluminium and titanium are oxidized anodically, the current through the oxide layer shows, during and after formation, a marked dependence on the applied field across the layer. This well-known fact, which has been the subject of a number of calculations and experiments, is also the subject of this paper.

Starting from the assumption that an anodic oxide layer on metals like Al and Ta has an amorphous structure, a relation between field and current during anodic oxidation is derived. It appears that this relation is somewhat different from the exponential relation usually derived in literature. With these formulae, it is possible to explain the various results obtained with the experiments presented in this paper. Probably, they may explain the rather different numerical results mentioned in the literature in the same way.

The consequences of the amorphous structure on a more detailed picture of the oxidation process, as proposed earlier, have also been calculated. The results point to a frequency dependence of one of the parameters, as was actually observed in the experiments. The observed agreement between theory and experiments has made it possible to calculate approximately the parameters introduced in this theory.

Problems in connection with Methods of Determining the Strength of Ceramic Materials.

By K. BJÖRKLUND. (From *Transactions of Chalmers University of Technology, Gothenburg, Sweden*, No. 193, 1958, 78 pages, 41 illustrations.)

THE two most common methods of determining the strength of ceramic materials, particularly porcelain, consist of measuring their bending strength and their tensile strength. Insofar as routine factory tests and mere comparisons of different materials are concerned, in certain cases tensile strength will indicate, more clearly than any other single physical property, the qualitative differences between two materials. As indicated in this paper, determination of tensile strength is preferable to

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The Joy Limberoller flexible conveyor idler is an ingenious device which considerably simplifies the construction and maintenance of conveyors. Its striking difference from the ordinary conveyor idler lies in its flexible 'spindle', this consists of a stranded steel cable with swaged-on steel end-pieces. Neoprene discs, picked out in orange on the illustrations for clearness, are bonded to the cable at suitable spacings in such a way as to be virtually integral with it, and the neoprene is continued between the discs so as to protect the cable.

The steel fittings at the shaft ends are carried in two-row deep-groove FBC bearings, with a neoprene seal. This seal has proved to be effective in excluding dirt and in retaining the lubricant. Thus, two bearings take the place of the usual six.

As will be seen from the illustration, the steel cable hangs in a natural catenary and thereby imposes not only the radial loading directly due to the weight on the conveyor, but combines with it a simultaneous end-thrust. The bearings—made to the requirements of Joy-Sullivan Ltd., by whose courtesy we reproduce these photographs—are formed with recesses in the housing, permitting instant changing of an idler assembly without the use of tools.

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that of bending strength, as it is more sensitive and reliable. In this connection, a method of determining the tensile strength of insulator porcelain is described, and this method appears to be less complicated than the *ASTM* method with regard to making testpieces, yet still gives satisfactory comparative values of the tensile strength of ceramic materials.

With regard to fundamental investigations into the strength of ceramic materials, it should be noted that knowledge is far from complete, and it is not possible to make exact calculations of the strength of these materials. Furthermore, just how strength is related to and influences the other properties of ceramic materials is by no means clear.

Among the properties relating to the strength of ceramic materials tensile strength must be considered the most important, and it is considered of primary interest to elucidate the conditions governing the value of tensile strength in such materials. In this connection, particular attention should be focused on the following problems :—

(a) The values generally show a considerable dispersion at experimental determinations, even when the materials exhibit a very high degree of isotropy and the experimental conditions are exceptionally favourable. This is a characteristic peculiarity of ceramic materials.

(b) Tensile strength is markedly dependent on the volume of the object subjected to the breaking strain. In particular, the size and quality of the surface layers appear to exert a decisive influence. When the volume of the object increases, tensile strength decreases.

(c) The dispersion of values also depends on the volume of the object. The larger the volume subjected to the load, the greater is the dispersion.

(d) Tensile strength evidently depends on the rate of increase of the load until a fracture occurs, increasing with an accelerated rate of load until a limiting value is reached. The influence of the rate of load on the dispersion of the values has not been investigated.

These peculiarities relating to the tensile strength of ceramic bodies must be the object of more complete, careful, and sustained investigations than have so far been carried out. In addition, it is recommended that both tensile strength and bending strength should be determined in each case.

Testing of Machinability by Radioactive Methods.
By B. COLDING. (From *Acta Polytechnica Scandinavica, Sweden*, Mechanical Engineering Series, No. 1, 1958, 73 pages, 40 illustrations.)

THE radioactive methods of testing machinability used in the research work described in this paper deal with the β-method and the γ-method, based on very short irradiations of carbide blanks, making use of the radiation from the tungsten isotope W^{187} (half-life = 24·1 hr). The tools used were all of the clamped type, and were each subjected in a reactor to a neutron flux of from about 10×10^{11} to 26×10^{11} neutrons/cm²-sec for periods between 20 minutes and 1 week, arriving at the laboratory 24 hours after irradiation was completed. Mounting of the radioactive tools was effected by remote handling, and the tests were carried out on an ordinary lathe, which was provided with a radiation shield. Wear on the carbide tools was determined by measuring the radioactivity of the chips obtained, which were collected at suitable time intervals in a box below the tool.

For the β-method, the β-radiation from small quantities of chips, of the order of 1 gram per sample, was measured by means of Geiger-Müller tubes of the end-window type. This method enabled separate measurements to be made of the wear on the clearance and rake sides of the tool. The γ-method was used to measure the total activity from both sides of the chips by means of a thick-walled Geiger-Müller tube, located longitudinally in a double cylinder holding approximately 250 gm of chips.

Numerous machinability tests were carried out in five different materials cut by these radioactive cutting tools. It was found that the rate of wear, after a fairly brief running-in period, was approximately constant up to the time the tool wore out, so that the mean activity in the chips produced during a few minutes turning constituted a relative measurement of the rate of wear. By means of a reference measurement, absolute values for the tool lives were obtained. The β- and γ-methods used gave approximately the same degree of accuracy, i.e., varying between $\pm 2\%$ and $\pm 20\%$ for about ten measurements. It was also established that the total cost of tests for a tool-life curve using the radioactive method is appreciably lower than the corresponding cost with conventional methods.

Computing the Strength of Turbo-Alternator End-Bells.
By W. KELLENBERGER. (From *The Brown Boveri Review, Switzerland*, Vol. 49, No. 3, March 1958, pp. 113–127, 16 illustrations.)

THE end-bells of large turbo-alternators are heavily stressed during the overspeed test, and high-alloy austenitic steel demands particular care from the manufacturing point of view. It is therefore essential to carry out comprehensive computation of the strength of the end-bells. This article indicates how an end-bell may be considered as a rigid cylindrical shell, a distinction being made between the symmetrical and the skew-symmetrical states.

After the end-bells of Brown-Boveri turbo-alternators have been shrunk on, the stresses are at least 50% of the maximum stress experienced by the end-bell. Prestressing due to shrinkage is incomplete, and maximum stress is experienced at overspeed, when the end-bell widens to such an extent that the original shrinkage is completely counteracted. The rotation of the end-bell is not "floating", since it makes contact with the rotor body, owing to the skew-symmetrical loading at the opposing points.

The stress at overspeed can, as an example, comprise about 35% from the effect of the symmetrical load due to the coil ends, about 58% from the inherent centrifugal force, and about 7% from the skew-symmetrical load on the end-coils alone. This latter portion is not necessarily governed by the magnitude of the skew-symmetrical load, but rather by the radial play between the end-bell and the seating. In other words, increasing the skew-symmetrical load beyond a certain figure by no means implies that the bending stress at the edge will increase, because this load can only exert as much influence as the radial play allows, and this can be controlled by means of the shrinkage, which itself can be freely selected within certain limits.

The admissible stress is to some extent a matter of discretion, in which the following points must be taken into account :—

(1) The preferred material for the manufacture of end-bells is non-magnetic, austenitic steel of high strength, but difficult to machine. The high yield point is attained by cold-working in a tangential direction.

(2) The artificially improved elastic limit is very close to the tensile strength of the steel and is, in fact, 75 to 90% of the tensile strength, thus leaving only a very small working margin.

(3) The overspeed figure (usually 120 to 125% of normal speed) at which the maximum stresses are experienced occurs only once, and even then is of relatively short duration.

(4) Computation of the stresses automatically involves the assumption of homogeneous, isotropic material, simple laws of elasticity, reliance on symmetry, etc.

Despite the above considerations, the present standard practice of allowing the stress to amount to 70 to 80% of the yield point appears to be sufficiently reliable to warrant its continuation. One condition, however, is that special care must be taken in the design of the end-bell to avoid stress concentrations (notches, ventilation holes, etc.) wherever possible, and to take effective steps to prevent stress corrosion.

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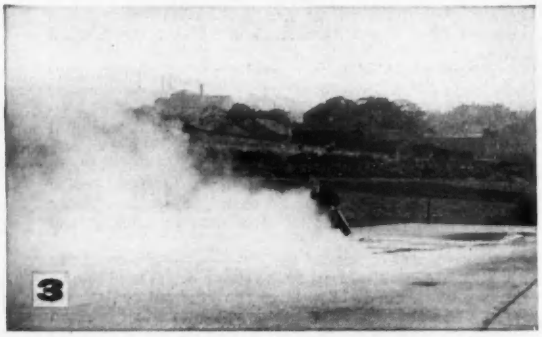

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New Materials, Processes, and Equipment

DEBURRING AND CHAMFERING MACHINE FOR GEARS AND SPLINES

A new type of duplex single-station deburring and chamfering machine for internal and external gears and splines has been developed by the Modern Industrial Engineering Co., of Detroit, Michigan. Designated " Burr-Master ", the new machine deburs and chamfers teeth on both sides of a gear at the same time, production being up to five teeth per second, both sides of the root and tooth being chamfered. The depth of chamfer is adjustable to meet specific manufacturing requirements, and the work cycle is automatic.

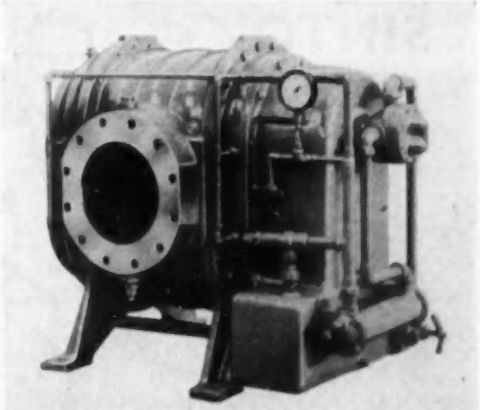
All moving parts in the head are machined and mounted in relation to a rocking tool-block holder of precision construction, which provides the generated cutting action. Positive positioning of the tool-block holder is assured, owing to the fact that it nests in the tool block and is keyed in two directions. Four socket-head screws hold the tool block in position, facilitating mounting or dismounting. The work-holding fixture is accurately located on fixture mounting rails, over hardened and ground dowels, and is also secured by four socket-head screws. Predetermined locating points on the platen rails are used to position the fixture. The cutter-head assembly, in turn, is positioned from predetermined points on the fixture. Since the cutter-head assembly rides on guide bars and is located by turning the feed screw either clockwise or counter-clockwise to move it in or out, location of the rocker mechanism in proper relation to the fixture for a specific part is accomplished very quickly. The cutting tool is positioned in proper relation to the gear by positive means, eliminating gauging or guess work.

Depth of cutting stroke, to provide the exact depth of chamfer desired, is infinitely adjustable by the simple process of loosening one nut on the adjustment plate. To change the cycle time required for a particular gear or spline, all that is necessary is to adjust a single screw in the electrical control panel. At the end of the cycle, an electric clutch stops the machine with the cutters withdrawn for loading and unloading.

ROOTS-TYPE BLOWERS AND GAS PUMPS

A completely new range of blowers and gas pumps, utilizing the basic Roots rotary positive principle and intended to provide more efficient handling of air and other gases, is announced by Roots-Connersville Blower, a division of Dresser Industries Inc., of Connersville, Indiana. The new blowers feature a vertical arrangement of the impellers, providing horizontal inlet and discharge connections for more convenient piping, and permitting savings in floor space of as much as 40%. The drive shaft extends from the lower impeller, matching more closely motor-shaft heights, while an improved segmented waist impeller shape permits safe handling of entrained liquids, with the added advantage of quieter operation.

A specially designed stub shaft permits a higher pressure rating for a given impeller length, delivering greater displacement without extremely high rotating speeds, and reducing overall dimensions to a minimum. External bearings and a separate oil reservoir are eliminated, further reducing the space requirements of the unit. Delivery of completely oil-free air or gas is assured by double seals on the shafts, i.e., a multiple labyrinth seal and a positive oil seal. All units are sized for direct connection to medium- and high-speed motors. V-belt drives may also be used for intermediate ratings up to approximately 200 hp. Speeds are well matched to gas- or diesel-engine speeds, while steam-turbine drives can be used with standard speed reducers.



The blowers, designated type RAS (illustrated) and gas pumps RGS, have identical volume and pressure ratings. Thirty-six sizes are offered, covering a capacity range of from 2000 to 14,000 cfm at 6 psig, and from 1500 to 8000 cfm at 10 psig. All parts of the blowers and gas pumps are identical (with the exception of the gas-pump bearing carrier and seal), thereby improving performance and simplifying maintenance and replacement of parts. The one-piece cylinder assures maximum rigidity and avoids difficult joints, resulting in a gas-tight machine. The standard unit is constructed of high-grade cast iron, but is readily adaptable to other materials, including aluminium, bronze, and stainless steel, in cases where weight or corrosion are important considerations.

dynamic technique

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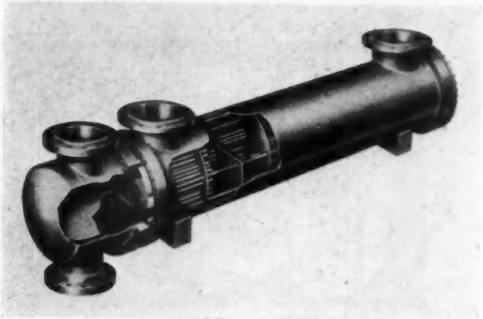
STANDARDIZED RANGE OF HEAT EXCHANGERS

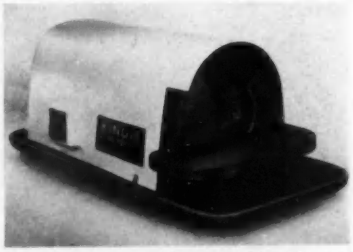
Specifically designed for the chemical industry, but also suitable for numerous general industrial applications, a new, fully standardized range of heat exchangers has been developed by American-Standard, Ross Heat-Exchanger Division, of Buffalo, N.Y. These units, designated type C-100, can be built to handle any combination of liquids or gases, can be readily assembled for a wide variety of process applications, and are adaptable for use as heaters, coolers, vaporizers, or condensers.



Extreme flexibility is provided by an extensive choice of materials, sizes, and arrangement of components, of mounting position, of tube side passes, and nozzle orientation. Available in one-, two-, and four-pass designs, these exchangers incorporate an externally packed floating head which prevents intermixing of fluids but allows for the expansion or contraction of the shell and tube bundle. Vertical-type units incorporate vents and drains, with drilled and tapped holes in the packed end-shell flange and the stationary tube-sheet for complete draining and venting of the shell side. This feature prevents corrosion of the tube-sheet occasioned by stagnant fluids. Moreover, since vapour pockets cannot form at the top of the shell during operation, full use is made of the entire effective tube surface.

DISC-TYPE FILING MACHINES

The latest model in the range of " Rindis " disc-type filing machines introduced by Lorant & Co. Ltd., of London, S.E.20, is their Rindis type RD.58/10, which is available either as a 10-in. bench model or a pedestal model. An inclinable work-table, adjustable towards the disc, is provided, and gives alternative height positions for accommodating work of varying thickness. The complete unit is mounted on a substantial tray, and the cover acts as a guard to the disc and also houses a rotary switch.



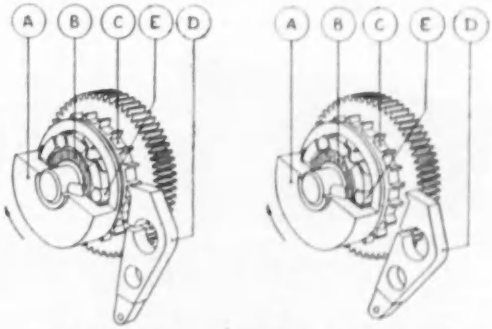
All the existing range of Lorant filing discs, with their various arrangements of teeth, can be used on this machine. An important feature of these discs is that they are double-sided and their teeth extend to the periphery and on the periphery face itself, when necessary, facilitating the filing of work across the complete face or at the corners. Whatever arrangement of teeth is used, i.e., straight, curved, hand-cut, etc., these discs, which are stated to remove material from four to six times faster than is possible by hand, operate without the need for abrasive or coolant. No clogging is experienced, and their shape is retained without redressing. When the cutting edges are dulled, the discs can be repeatedly resharpened very economically. The wide variety of teeth arrangements ensures maximum efficiency on all types of materials, including aluminium and its alloys, brass, copper, lead, steel, and thermoplastic and thermosetting plastics.

Two-speed models are offered as standard. If required, they can also be supplied with bar-feed attachments for the automatic generation of parts from various types of metals.

ROLLER CLUTCH

A new roller clutch, believed to be the first of its kind, has been introduced by Tiltman Langley Limited, of Redhill Aerodrome, Surrey. Robust, compact, and equally efficient under all climatic conditions, the new clutch has a positive drive and is capable of transmitting up to about ½ hp at 1500 rpm.

The illustration shows the essential components of the clutch in the disengaged position (left) and in the engaged position (right), the housing *A* being the driving member and shown driving in a clockwise direction. In the disengaged position, the control wheel *C*, which is combined with the roller cage, is held stationary by the action of the pawl *D*, preventing the rollers *E* from being driven into the wedge formed by the housing *A* and the cam *B*, which is attached to the output gear. In the engaged position, the control wheel *C* is released by withdrawal of the pawl *D*, and moves in a clockwise direction, as the result of the friction of the springs between the cage and the housing, thus driving the rollers into engagement. When the control wheel *C* is stopped, the rollers are kicked out of engagement, and the clutch reverts to the disengaged position.

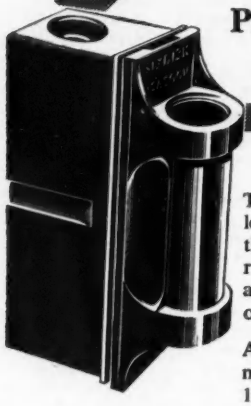


The pawl *D* and its control mechanism, which may be operated mechanically or by a low-power (7-W) solenoid, can be mounted in relation to the control wheel *C* in various ways, with a view to taking care of different directions of rotation or to catering for varying installation requirements.

DOUBLE-ENDING MACHINE FOR PIPELINE WELDING

Developed to speed up the process of pipeline welding on site, a new double-ending machine, produced by Quasi-Arc Limited, of Bilston, Staffs., enables two 30- to 40-ft lengths of pipe to be welded together automatically, after which the double length is joined to the pipeline by conventional manual stove-pipe welding methods.

In operation, the length of pipe is supported on two idler units, each of which incorporates six ball castors arranged in V-formation. This method of mounting not only enables the pipe to be rotated for welding, but allows it to be withdrawn in the longitudinal direction. It also means that pipes of 6 to 38 in. in diameter can be accom-



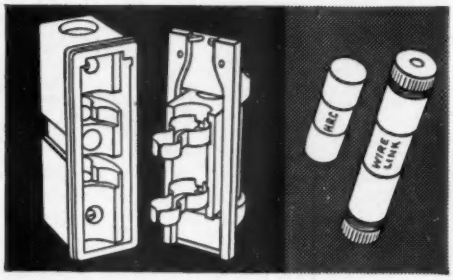
VIBRATION PROOF FUSES

from 5 to 100 amps

The Slydlock series of fuse units are vibration proof—which means they have been extensively tested for use under the most arduous working conditions. This is but one example of the technical progress made by Wilcox in the design and manufacture of fuses over the past 30 years.

The fuse shown left is typical of the Slydlok 'H' range and is available in 5, 15 or 30 amp ratings

An exploded view is shown on right. This fuse enables the employment of either H.R.C Cartridges or semi-enclosed fuse-links, as illustrated.



Also available are the Slydlok 'G' series medium duty fuse units in 15, 30, 60 and 100 amps, rewireable or H.R.C.

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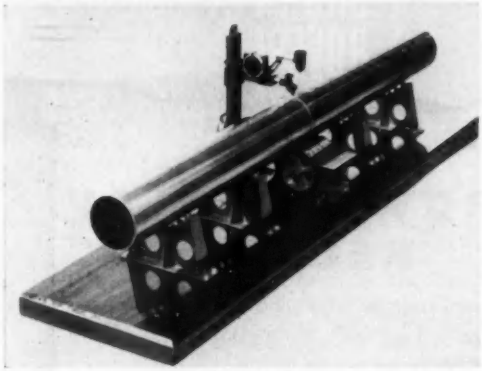
modated without any adjustment. The two pipes to be butt-welded are loaded onto the idler units, with their ends butting together, and are rotated by two pairs of large-diameter rolls, each pair being driven by a ½-hp motor. The two motors are supplied with direct current from a motor-driven generator with Ward-Leonard control, and reduction gearing enables the welding speed to be varied from 7 to 70 ipm.



Pipes between 6 and 26 in. in diameter can be rotated without any adjustment to the height of the drive rolls, and only slight adjustment of the rolls is needed to engage and disengage the pipe. This adjustment is operated by a handwheel rotating a leadscrew with right- and left-hand threads to move both carriages simultaneously. Slight variations in loading are taken up by thick rubber tyres on the rolls. The vertical frame on which the welding-head carriage runs forms a single integral unit with the roller-bed frame and is of simple construction. The arm carriage is raised and lowered manually, the arm being counterbalanced, and can be clamped at any desired height. The welding head (Fusarc/CO_2, Fusarc, or Unionmelt), can be adjusted to the required position relative to top dead centre of the vessel and clamped, and has standard vertical and traverse slides for fine adjustment.

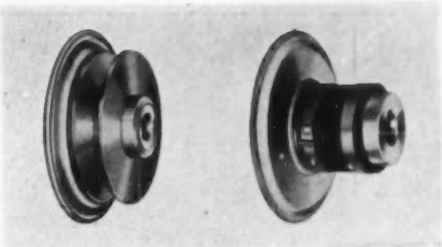
MACHINABLE CEMENTED CARBIDE

Development of a machinable carbide is announced by the Sintercast Corporation or America, of Yonkers, New York. Combining the advantages of conventional carbides with those of tool steels, the new material, designated " Ferro-Tic ", has a structure consisting of extremely hard titanium carbide grains embedded in a steel matrix. The resulting composite material can be heat-treated in the same way as a tool steel, the hardening operation involving oil-quenching from 1700° F.

In the annealed state, Ferro-Tic is readily machinable, and metal-removal operations, such as turning, milling, drilling, and sawing, can readily be performed, permitting users to fit the carbide to their needs. Thus, as distinct from conventional tungsten carbide or cast cobalt alloys, which must be purchased to size for a specific application, any standard blank of Ferro-Tic can be transformed into the desired part. Carbide components requiring a highly complex geometric form, e.g., those with a multiplicity of holes, thin walls, or drastic changes in cross-section, can therefore be fabricated at a fraction of the cost of tungsten carbide sections.

DRY-FLUID DRIVES AND COUPLINGS

Designed for fractional-horsepower applications at speeds up to 1750 rpm, a new series of compact " Flexidyne " dry-fluid drives and couplings developed by the Dodge Manufacturing Corporation, of Mishawaka, Indiana, is specially suitable for use with light machines subject to jamming or with small motors handling heavy



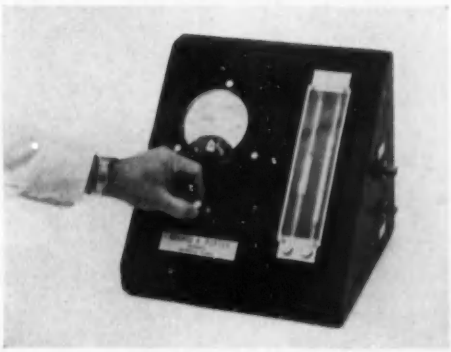
loads, providing cushioned starting, 100% efficiency at full load, and protection against overload.

The dry-fluid medium in these drives and couplings, designated types 5D and 5C, is small heat-treated steel shot, a measured amount of which is contained in the housing. Inside the housing, which is keyed to the motor shaft, is a rotor, free to rotate relative to the housing, but connected to the load. When the motor is started, centrifugal force throws the charge of steel shot to the perimeter of the housing, packing it between the housing and the rotor, which transmits power to the load. Initial slippage is momentary, and the housing and rotor then become locked together, achieving full-load speed without slip.

The illustration shows (left) a typical type 5D " Flexidyne " dry-fluid drive, and (right) a type 5C coupling.

MICRO-FLOW METER FOR GASES

Developed to measure flows of gases and vapours as low as 1 cc per hour up to 10 cc per minute and higher, a new micro-flow meter introduced by George K. Porter Inc., of Hatfield, Penn., has a wide range of applications, not only in research laboratories, but in various industries, including instrument manufacturing, glass, pharmaceutical, petroleum, and rubber. Actually, the instrument has three basic uses, i.e., as a means of measuring and indicating flows from the small-flow to the micro-flow region, as a low-flow calibration unit, and as a flow setting system for establishing specific flow rates.



The meter, which can be used with virtually any type of vapour or gas, either corrosive or non-corrosive, eliminates the difficulties of measuring very low flows with conventional flow-measuring systems by providing a sensitive flow signal in the form of a low-level differential pressure across a precision-formed micro-flow channel, a sensitive differential pressure gauge providing the read-out flow indication. The instrument can easily be modified to measure various flow ranges merely by replacing the micro-flow channel tube with another tube, numerous designs of which are produced to cover different flow requirements. In addition, the meter is available in versions providing a d.c. or a.c. signal, suitable for standard recorders and controllers.

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NEWS OF THE MONTH

PERSONAL

Mr. George Butler, A.M.I.Prod.E., chief designer of The Butler Machine Tool Co. Ltd., has been appointed to the board of directors of the company.

To strengthen their team of engineers engaged on projects associated with the U.K. nuclear-power programmes and other applications of nuclear energy, Sperry Gyroscope Company Ltd. has recently appointed **Mr. J. Walker, M.A., A.M.I.E.E.,** to a senior post in their engineering division.

Mr. I. A. Ferguson, M.I.E.E., Mr. P. S. Clayton, B.Sc., A.M.I.E.E., A.M.I.Mech.E., and Mr. J. B. Siddaway, B.Sc. (Hons.), have been appointed managers of Large Electrical Machine Sales, Power-Rectifier Sales, and Compressor Sales, respectively, of the newly formed A.I.E. Heavy Plant Division, managed by The British Thomson-Houston Co. Ltd.

Mr. J. Strong, M.A., executive director of British Oxygen Gases Limited, has been elected president of the Institute of Welding for 1958–59, in succession to **Sir Charles Lillicrap, K.C.B., M.B.E. Mr. A. Clifford Hartley, C.B.E., F.C.G.I., B.Sc.Eng., M.I.C.E., M.I.Mech.E., F.Inst.Pet., Mr. G. Roberts, B.Sc. M.I.C.E.,** and **Mr. E. Seymour-Semper, M.I.Mech.E.,** have been elected vice-presidents for the same period.

Mr. Walter W. Jeacock, M.I.P.E., has been appointed general manager of Coventry Gauge & Tool Co. Ltd., in succession to the late **Mr. Arthur J. Hewitt, O.B.E.**

The Goodyear Tyre & Rubber Co. (Gt. Britain) Ltd. announce the appointment of **Mr. W. J. Gaffney** as chief engineer for all their production plants in Great Britain. Mr. Gaffney was formerly manager of engineering and maintenance at the Wolverhampton plant—a position which **Mr. R. E. Ward,** of Akron, Ohio, recently took over.

The election of **Mr. F. Gordon Kay** to their board of directors has been announced by Acheson Colloids Limited.

E.M.I. Electronics Ltd. announce the appointment of **Mr. K. Elphinstone, M.B.E.,** as export manager.

Mr. Sidney Allen, M.I.Mech.E., F.R.Ae.S., has been appointed chief engineer for all products, except motor cars, of Armstrong Siddeley Motors Limited.

Stockdale Engineering Ltd. announce that **Mr. G. P. Balfour, B.Sc., A.C.G.I., A.M.I.Chem.E.,** has been appointed managing director.

Mr. H. E. Cox, A.M.I.E.E., has joined the board of directors of The British Thomson-Houston Co., Ltd.

Mr. P. W. Faulkner, O.B.E., general manager of the Chemical and Metallurgical Division of The Plessey Company Limited since 1953, has been appointed a director and general manager of Plessey International Limited.

Siemens Edison Swan Ltd. announce the appointments of **Mr. R. G. Holland, A.M.I.E.E.,** as assistant cable sales manager, special contracts, and **Mr. R. B. Tucker** as assistant sales manager, rubber and plastic cable division.

Mr. R. T. Hayes has been appointed a director of United Coke and Chemicals Company, Limited, a subsidiary of The United Steel Companies, Limited.

Mr. Robert Young has been appointed chief inspector of the Salterpak Division of Geo. Salter & Co., Ltd.

Mr. A. W. Field, B.Sc., F.B.I.M., A.M.I.Mech.E., has been appointed deputy managing director of Mawdsley's Limited, of Dursley.

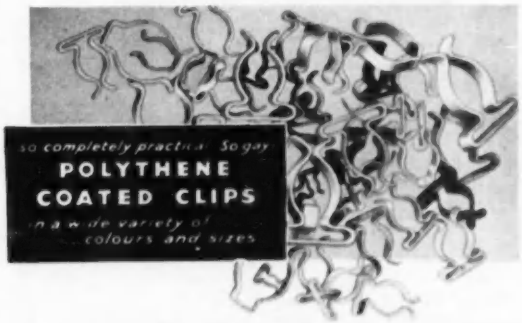
Mr. J. R. Munro, director of manufacturing and acting manager of the new Glasgow plant of the Caterpillar Tractor Co. Ltd., has been elected a vice-president of the parent company in Peoria, Illinois, and will assume administrative responsibility for the activities of the manufacturing division, which will encompass the functions of manufacturing general office, purchasing general office, and traffic general office.

Mr. John Collins, commercial manager of the Liverpool and Netherton works of The English Electric Company Limited, has been elected chairman of the Mersey and North Wales Centre of the Institution of Electrical Engineers for the 1958/1959 session.

Associated Commercial Vehicles Ltd. announce that **Mr. A. S. C. Chattey,** chairman of A.C.V. Sales Ltd., has retired, and will be succeeded by **Mr. Eric Hollands,** who has been appointed director and general manager.

Venner Electronics Ltd. have appointed **Mr. E. F. Dunkin, Grad. I.E.E.,** as their U.K. sales engineer, responsible for technical liaison and sales promotion of the company's range of transistorized packaged units and test equipment.

Mr. E. Loram has been appointed general sales manager of Small & Parkes Ltd.



Proof against atmospheric corrosion and many chemicals, insulated, immune to mould, happy in temperatures up to boiling point, these clips have many uses. Sizes to grip range from ¼ to 2 inches and colours available are black, white, grey, blue, red and green.

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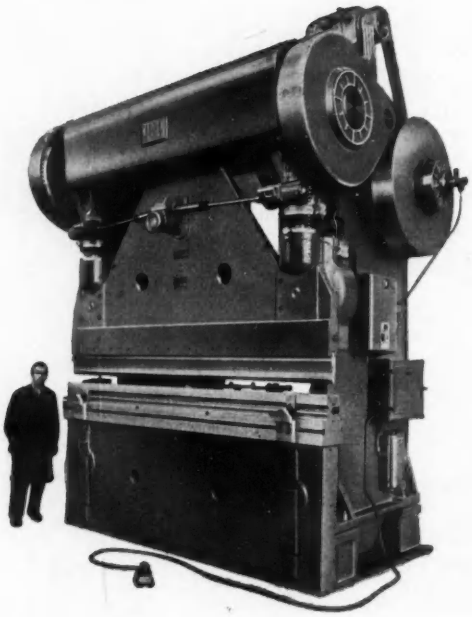

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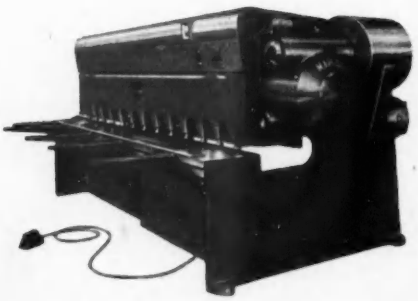

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BUSINESS NOTES

Charles Baynes Ltd., manufacturers of " Ding-Dong " hacksaw blades and frames, have appointed Mr. J. Barry Young, of 104 Percy Street, Newcastle-upon-Tyne, as their representative for Scotland and the North-East Coast area.

The Peterhead factory of **Cleveland Twist Drill (Great Britain) Ltd.** is to be extended. This decision follows the completion of the original factory less than a year ago, and represents the implementation of a further step in the company's expansion programme, permitting increased production and, in due course, an extended range of products. The new extension includes both manufacturing and office space and will amount to 35,000 sq ft, bringing the total floor area at Peterhead to over 100,000 sq ft. Construction will be carried out by **Scottish Industrial Estates Limited,** who also built the original factory, and it is hoped that the new facilities will be in use within twelve months.

It is announced by **Evode Limited** that, together with their associate companies, **Evomastics Limited** and **English Waxes Limited,** they have moved their London office to 82 Victoria Street, London, S.W.1. (Tel. :—ABBey 4622).

J. & J. Neil (Temple) Limited, of Temple Park Iron Works, Glasgow, W.3, have been appointed sole representatives in Scotland for **Bennis Combustion Limited,** of Walkden, Manchester, and for **Bennis Mechanizations Limited** and for the **Saxon Engineering Company Limited,** both of Fenton, Stoke-on-Trent. All these companies are members of the Hodgkinson Group. The London office of Bennis Combustion Limited, Bennis Mechanizations Limited, and the Saxon Engineering Company Limited have now been moved to Brettenham House, Lancaster Place, London, W.C.2. (Tel. :—COVent Garden 2188/2189), which is also the London office address of the parent company, **James Hodgkinson (Salford) Limited.**

After a long association with **James Ferguson & Munro Ltd.**, it has been decided, as a matter of policy, by **Evershed & Vignoles Ltd.,** to terminate the agency and to have direct representation in Scotland. The Scottish area office is at 13 Rutland Street, Edinburgh 1 (Tel.: Fountainbridge 3058), and is under the management of Mr. R. M. Wardrop, B.Sc.

Two A.E.I. divisions became operative on July 1, 1958, these being the **A.E.I. Turbine-Generator Division,** managed by **Metropolitan-Vickers Electrical Company,** and the **A.E.I. Heavy Plant Division,** managed by the **British Thomson-Houston Company.** These divisions will handle the design, manufacture, and sales of all products falling within these categories. The headquarters of the Turbine-Generator Division is at Metropolitan-Vickers, Trafford Park, Manchester 17, and of the Heavy Plant Division at British Thomson-Houston, Rugby.

Chemical Construction (Great Britain) Limited have moved to new premises at Henrietta House, Henrietta Place, London, W.1 (Tel.: LANgham 6571).

Crofts Engineers (Holdings) Limited announce the opening of a subsidiary company, **Crofts U.S.A. Limited,** with headquarters in Chicago, to deal with their trading activities in the U.S.A.

Cawkell Research & Electronics Ltd., formerly **A. E. Cawkell,** have now moved into larger premises in Scotts Road, Southall, Middlesex. (Tel. :—SOUthall 3702/5881).

It is announced by **Babcock & Wilcox Limited** that, following many years of successful co-operation with **The Babcock & Wilcox Company,** of America, in the design of conventional steam-raising plant, these two companies have now extended their technical collaboration into the nuclear-power field.

According to a preliminary announcement by the directors of **Rockwell Engineers Limited** and those of the **Coventry Gauge & Tool Co. Ltd.**, agreement in principle has been reached regarding a merger of these two concerns. It is envisaged that this will be achieved by the acquisition by Coventry Gauge & Tool Co. Ltd. of the whole share capital of Rockwell Engineers Ltd. On completion of the merger, Mr. C. E. Rockwell and Mr. J. Middleton (who, with their families, hold a total of about 70% of the share capital of Rockwell Engineers Ltd.) would join the board of Coventry Gauge & Tool Co. Ltd. The **Rockwell Machine Tool Company Limited** will, in any case, continue to operate under its own name.

Firth Cleveland Instruments Limited, of Glamorgan, a subsidiary of **Simmonds Aerocessories Limited,** in the **Firth Cleveland Group** of companies, announce that they have concluded a licensing agreement with the **Gilbert & Barker Manufacturing Co.,** of West Springfield, Mass., U.S.A., to manufacture and market the Gilbarco electronic tank-contents gauge.

The administrative offices of **Kelvin & Hughes (Industrial) Limited** have been moved from London to their new building in Empire Way, Wembley, Middlesex (Tel. :—WEMbley 8888).

The Northern Area office of **Opperman Gears Limited** has been transferred from Leeds to Manchester, the new address being 20 St. Ann's Square, Manchester 2 (Tel. :—Blackfriars 6451). The Manchester office will be under the supervision of the Northern Area manager, Mr. M. G. Marsh.

Readers are reminded that the Glasgow office of the **Ransome & Marles Bearing Company Limited,** of Newark-on-Trent, is no longer at Bothwell Street, but at 380 Argyle Street (Tel. :—Central 3948).

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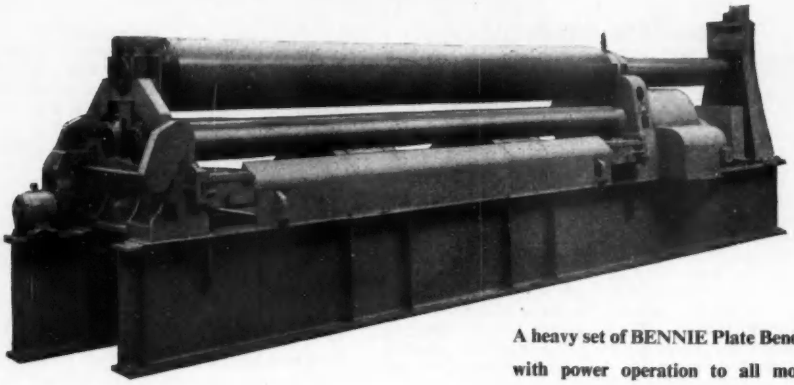

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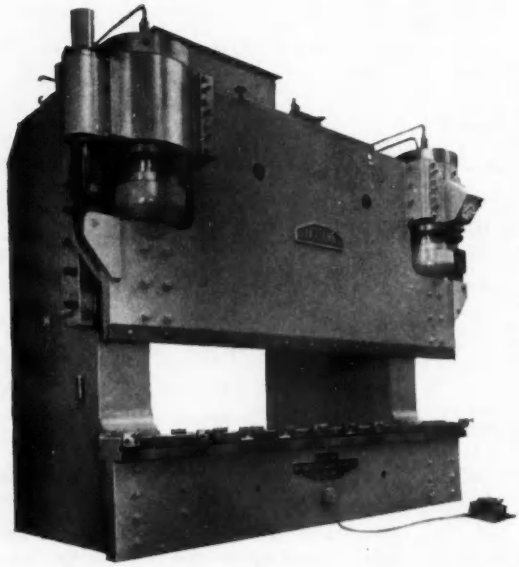

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58, Victoria Street, London, S.W.1. *VICTORIA 2106*

2, Sir Harry's Road, Edgbaston, Birmingham, 5. *CALTHORPE 2541*

The Building Centre, Brunswick Terrace, Leeds, 2. *LEEDS 25250*

CONTRACTS

Orders to the value of £70,000 for Bennes-Marrel multi-bucket hydraulic lifting and haulage units, including one for the supply of a fleet to The Steel Company of Wales, are announced by Aero Maintenance Equipment Ltd., London, one of the Arusha Group of Companies, who are the sole concessionaires in this country. Units are also being supplied to Trinoil of Trinidad, to Bridgwaters of Epsom, and to Metal Agencies, of Bristol.

Heenan & Froude Limited, of Worcester, are to supply more than 120 Heenan tubular air coolers to the English Electric Company Ltd., for use in the American Priest Rapids dam. The coolers will be used for the closed-circuit ventilation and cooling of the ten vertical-shaft water-turbine alternators (twelve coolers to each alternator). Two additional coolers will be supplied as reserves. Heenan & Froude have also secured a further contract from the English Electric Company for the supply of specially designed tubular coolers for the lubricating oil of the main thrust-blocks of these sets.

VHF radio-telephone equipment, valued at £15,000, to be installed for The Bahrein Petroleum Company Limited, an affiliate of the California Texas Oil Company Limited, is being supplied by the Automatic Telephone & Electric Company Limited, of London, W.C.2. The equipment has been made by A.T.E. (Bridgnorth) Limited, and will consist of fifteen FM radio links, including five " country sets ", connecting the administrative headquarters of The Bahrein Petroleum Company Limited at Awali, Bahrein Islands, with important outlying points. There will be four links to the refinery and four to the public-telephone network at Manama, as well as single links to the tank-farm, wharf, and other locations.

Film Cooling Towers (1925) Ltd. have been informed by the Central Electricity Generating Board that their tender for four natural-draught cooling towers for Rugeley Generating Station, Staffordshire, has been accepted. The value of the contract is in excess of £750,000 and will be carried out in collaboration with J. L. Kier & Co. Ltd.

Yorkshire Engine Company, Limited, Sheffield, a branch of The United Steel Companies, Limited, have obtained an order worth £350,000 for the supply of sixteen diesel-electric shunting locomotives to the Port of London Authority. The first of the new locomotives is due for delivery in April 1959. Some of the locomotives will be twin-engined 400-hp units similar to those already operating at Tilbury, and the others will be powered by single 300-hp engines. All the engines are of Rolls-Royce manufacture, and the electrical equipment will be supplied by The British Thomson-Houston Company, Limited.

The East German Government, through D.I.A. Maschinen Export in East Berlin, have signed contracts with E. P. Allam & Company Ltd., for the supply of concrete vibrating and finishing equipment to a value of over £5000.

A contract, of a total value approaching £1,000,000, has been awarded to Babcock & Wilcox Limited by the Central Electricity Generating Board, for the whole of the coal-, ash-, and dust-handling installation to serve the new Northfleet power station, near Gravesend, Kent. This installation will ultimately serve a total of six pulverized-coal fired boilers, each supplying steam to a 120,000-kW turbo-generator. The coal plant, with a capacity of 1600 tons per hour, will handle the seaborne coal from the Thames quayside, via belt conveyors, to the boiler house or out to the coal store. The dust-handling system, capable of dealing with 210 tons per hour, will convey the dust from the dust-collection points over a distance of 2600 ft to the storage bunkers, where it will be wet-conditioned for disposal by lorry.

SYMPOSIUM ON NUCLEAR FUEL CYCLES

The Institute of Physics, one of the constituent bodies of the British Nuclear Energy Conference, announces that it is arranging a Symposium in London on " Nuclear Fuel Cycles " on January 22 and 23, 1959. The programme is as follows :—

Session 1 : (a) Long term reactivity changes.
(b) Theory of once-through fuel cycles.
(c) Perturbations due to fuel cycles.

Session 2 : Optimization of fuel cycles for nuclear power stations.

Session 3 : Fuel cycle operational problems.

The papers which have been invited will cater mainly for those working in the field, and will deal with the applied-physics aspects of the fuel cycles which form the basis of the immediate nuclear-power programme. Abstracts (but not pre-prints) of the papers to be read or presented at the Symposium will be available early in January.

Application forms for tickets to attend the Symposium are obtainable from the Secretary of The Institute of Physics, 47 Belgrave Square, London S.W.1, and should be returned as soon as possible. The Symposium will be published in the Journal of the British Nuclear Energy Conference.

ELECTRONIC FORUM FOR INDUSTRY

Following the formation of the Data Processing Section of the Electronic Engineering Association (formerly the Radio Communication and Electronic Engineering Association), conversations have been held with other associations interested in this field, either as manufacturers or users. The aim is to provide a clearing house for the exchange of information as a step towards co-ordinating technical committee work, research, development, and application of the new techniques in industry. It is also hoped to provide a channel for the presentation of the British industry point of view in international discussions concerned with electronic automation and computation.

So far, discussions have been entirely on a technical level. Meanwhile, the name " Electronic Forum for Industry " has been adopted by those attending the meetings. The secretaries of the Forum are the Electronic Engineering Association, 11 Green Street, London, W.1 (Tel.: MAYfair 7874).

ELASTOMERS RESEARCH LABORATORY

To assist rubber manufacturers in the U.K. and on the Continent in taking advantage of the latest advances in research, testing, and manufacturing processes, the Du Pont Company (United Kingdom) Limited will construct an elastomers research laboratory at Hemel Hempstead, Hertfordshire. Covering 10,000 sq ft, the new laboratory will duplicate mill equipment and conditions found in the British rubber-processing industry, and much research will be directed to solving problems of individual plants, including the compounding, processing, and testing of all types of synthetic-rubber compositions and products. The laboratory will be equipped with mills and internal mixers, processing machines such as calenders and extruders, and steam-heated hydraulic presses, autoclaves, and circulating-air ovens for vulcanizing. Special machinery for preparing solutions and water dispersions of neoprene will be provided. Similar equipment will be installed for processing other synthetic rubbers, including urethane rubber.

In addition to the mill equipment, machines and devices will be installed to test the tensile strength, abrasion resistance, hardness, flex resistance, compression set, and chemical resistance of elastomers and elastomeric compounds, both at the time of manufacture and after ageing under various conditions.

The research and technical staff will be responsible for developing and testing new formulations and processing techniques using Du Pont elastomers, alone or

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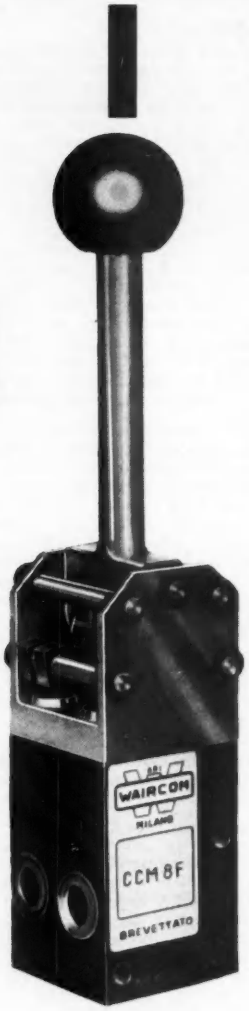

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in blends, for the manufacture of specific finished products. In this way, experimental formulations with optimum processing characteristics will be developed to produce highest quality at lowest cost. In addition to testing and research, the laboratory will be used as a demonstration and proving area. Testing of products made from Du Pont synthetic rubbers will be demonstrated on equipment designed to simulate actual service conditions. Engineers and other technical experts in the rubber industry will be encouraged to visit this laboratory to observe and evaluate experimental methods of compounding, processing, and testing. Another function of the laboratory will be to work with the rubber industry in the United Kingdom and Europe in establishing standards of quality and uniformity.

NEW OIL REFINERY AT MILFORD HAVEN

Esso Petroleum Company, Limited announces that a decision has now been made to proceed with building the refinery and marine installation at its site near Milford Haven, and work on the site will start immediately. The estimated cost of construction is £18,000,000. The new refinery is planned initially to process 4,500,000 tons of crude oil per annum, i.e., about 3,500,000 gallons per day. The principal products manufactured will be petrols, jet fuels, diesel fuels, marine fuels, and industrial fuels.

The most modern pollution-control measures will be incorporated in the new refinery, including air cooling, rather than salt-water cooling, for all major refining units. The marine terminal will be capable of handling simultaneously two tankers of up to 100,000 deadweight tons each, but this terminal can be expanded in the future, if necessary. In order not to disturb the current and silt-deposition pattern in the Haven, the berth will be of open-pile construction.

NEW MEDICAL FILM ON RESUSCITATION

The British Oxygen Film Unit has recently completed an instructional colour film on the Stephenson system of resuscitation. Covering the construction, operation, and maintenance of the Stephenson "Minuteman" resuscitator, the film also demonstrates the techniques for its use. The needs of industrial safety and welfare officers; works medical officers and medical officers of health; fire, ambulance, and Civil Defence authorities; and baths superintendents have been especially considered in its production.

The film (16-mm, sound, running time 20 min) is available on free loan from: British Oxygen Gases Ltd., Medical Division, Great West Road, Brentford, Middlesex. Copies are also available for outright purchase.

THE ITALIAN MACHINE-TOOL INDUSTRY

In view of the fact that no European Machine-Tool Exhibition is scheduled to be held in 1958, it has been decided by the Italian Machine-Tool Manufacturers Association (U.C.I.M.U.) to hold an exhibition of machine tools and allied equipment in Milan between September 11 and 21, at which not only Italian products will be strongly represented but also those of foreign manufacturers through their Italian representatives.

Incidentally, there can be no doubt that, despite the grave difficulties, both political and social, which confronted the Italian machine-tool industry as a whole after the war, it has now firmly established itself as a producer of first-class equipment, capable of competing in every way with that manufactured by any other country in the world. Thus, the production of Italian machine tools for metal working was about 10½% higher in 1957 than in 1956, the respective figures being about 26,000 tons and 23,550 tons. Similarly, exports have shown an improvement, the relevant figures being about 8050 tons in 1954, 8170 tons in 1955, 11,300 tons in 1956, and 14,110 tons in 1957. Imports have also increased, ranging from about 14,060 tons in 1954 to about 15,170 tons in 1957.

With the advent of the Common European Market and of a wider free-trade area, there can be no doubt that Italian machine-tool manufacturers, like those of other countries, will direct their efforts to coping with the new situation. Certainly, the expansion of the potential market, and the more rapid distribution of goods, capital, and ideas will promote a definitely healthy spirit of competition; in this connection, Italy, by virtue of her technical and administrative efficiency, has nothing to fear.

NEW CANADIAN ALUMINIUM SMELTER

The first stage of what will ultimately be the largest installation of multi-anode pumpless rectifiers in the world for the production of aluminium was officially opened recently at Baie Comeau in the Province of Quebec, marking an important milestone in the history of Canadian economic development. The new aluminium smelter is a joint British-Canadian venture. The British Thomson-Houston Company has been entrusted with the design, manufacture, and installation of the complete power conversion plant for Stages (1) and (2), comprising transformers, rectifiers, switchgear, and ancillary equipment, including motors.

Each furnace series, or pot line, requires a d.c. current of 100,000 A at 850 V. The smelting process is continuous, and the electrical supply must therefore remain uninterrupted; consequently, the plant is designed so that any portion of the equipment can be withdrawn from service for inspection or maintenance without reducing the power output. The conversion plant is arranged in eight units, any seven of which can maintain the full output required for the pot line. Each unit consists of a single rectifier transformer—believed to be the largest of its type in the world—coupled to a bank of eighteen truck-mounted cubicle-enclosed pumpless steel-tank mercury-arc rectifiers. This form of enclosure provides a degree of protection and accessibility not generally found

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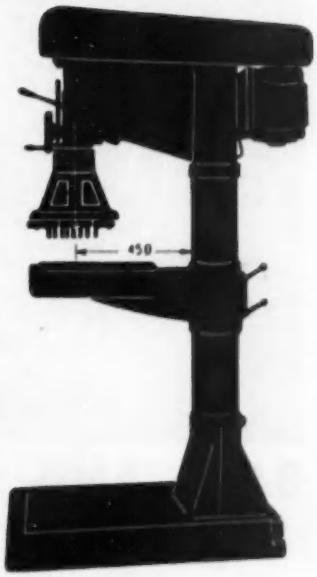

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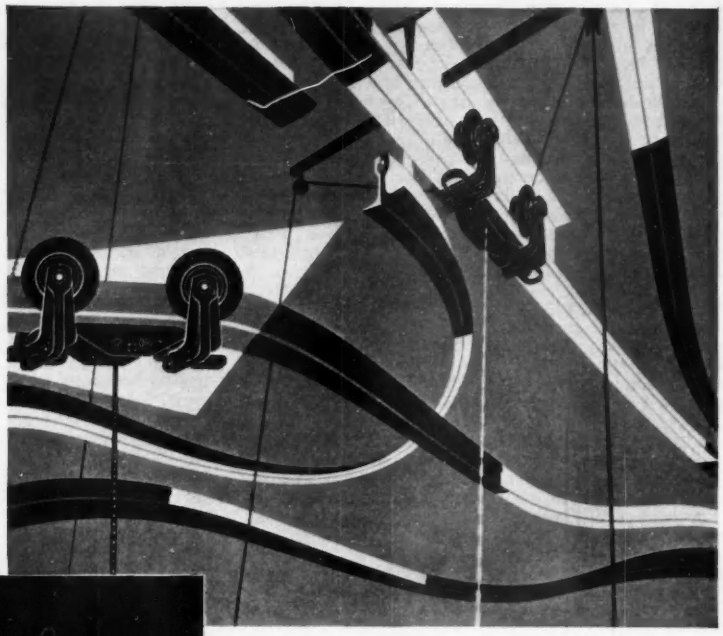

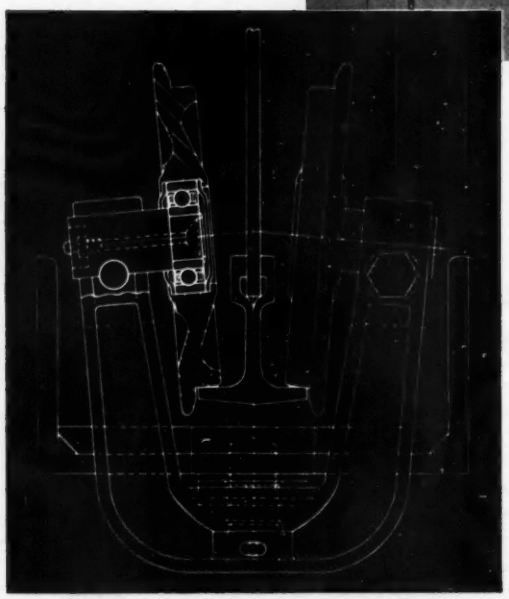

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in Canada for equipment of this size. The transformers incorporate, as part of the main internal assembly, a phase-shifting transformer which enables 48-phase overall operation to be achieved with eight units in service.

The plant was commissioned ahead of schedule and, at the official opening, the Stage (1) installation was delivering its full rated output. The second stage of construction at Baie Comeau is well advanced and should also be commissioned ahead of schedule.

NEW COLD-ROLLING PLANT FOR STEEL, PEECH AND TOZER

Steel, Peech and Tozer, a branch of The United Steel Companies, Limited, are to spend over £1,750,000 on the installation of a cold-rolling mill and ancillary equipment adjacent to their Brinsworth continuous medium-width hot-strip mill. The new plant is planned to be in operation in two years' time.

The Brinsworth mill, completed last autumn, is the only mill of its kind in the country and is engaged in the continuous production of thin steel strip up to 18 in. wide. The bulk of its output is at present supplied in the hot-rolled condition, but when the new cold mill comes into service, up to 2000 tons of steel a week will receive a cold reduction after hot-rolling.

After pickling, coils of hot-rolled strip will be transferred to a tandem cold-rolling mill and then annealed in either of two continuous annealing furnaces, each with a capacity of five tons per hour and fired by coke-oven gas. The strip will then be rolled in a skin pass mill to improve metallurgical properties after the annealing process and to impart a good surface finish, and will be slit to the required width in one of a number of slitting machines. The mill will be capable of cold-rolling strip up to 18 in. wide to thicknesses from 0·25 to 0·010 in. Although able to deal with all qualities of steel, it will be primarily employed on the cold-rolling of carbon steels.

The existing cold-rolling department at Steel, Peech and Tozer, which produces narrow steel strip for the strapping, tube, and bicycle industries, will not be affected by this new development.

ELECTRONIC COMPUTER EXHIBITION

The Electronic Computer Exhibition, the first of its kind in Europe, is to be held under the patronage of H.R.H. The Duke of Edinburgh at Olympia, London, from November 28 to December 4, 1958. Concurrently with the Exhibition there will be held a Business Computer Symposium. The Exhibition and the Symposium have been organized at the instigation of the National Research Development Corporation by the Electronic Engineering Association and the Office Appliance and Business Equipment Trades Association.

The Exhibition will be thoroughly representative of the British electronic computer industry and will show the outstanding contributions already made by British manufacturers to the development and use of electronic computers and data processing equipment. Visitors will be able to judge the progress made in the application of electronic computers in achieving greater productivity in office and factory, while a comprehensive display of computers and ancillary equipment will cover research and application by leading business organizations and will show how computers have an immediate bearing on the many intricate problems of management to-day. The British effort has not been confined to large-scale computers, but more particularly with medium-sized electronic computers suitable for every type and size of organization in government, industry, and commerce.

The Business Computer Symposium will be held during the Exhibition, on December 1, 2, and 3. At six sessions, executives from a wide range of concerns of diverse nature and size, both private and State enterprises, will give management the benefit of their own practical experience in applying electronic computer techniques to their particular problems. Delegates will be invited to question the speakers and derive the maximum benefit from their knowledge and experience of computers and computer application.

For further details of the Exhibition and Symposium and for a delegate's enrolment form, communications should be addressed to Mrs. S. S. Elliott, M.B.E., Electronic Computer Exhibition and Business Symposium, 11/13 Dowgate Hill, London, E.C.4. Tel: CENtral 7771/2.

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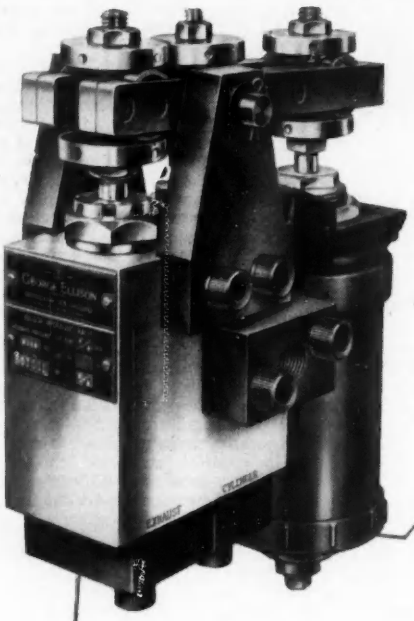

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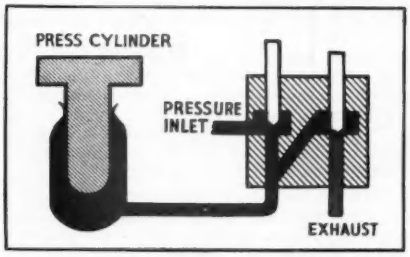

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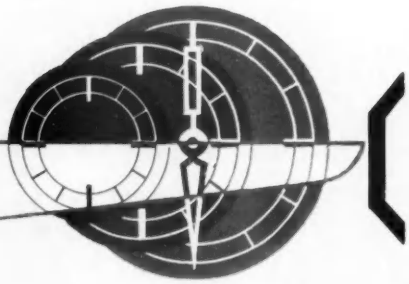

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The Performance and Design of A.C. Commutator Motors. By E. Openshaw Taylor, B.Sc., A.C.G.I., D.I.C., M.I.E.E., M.Amer.I.E.E., F.R.S.E. 368 pp., 231 illustrations. Publishers : Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price : 45/–.

The gradual elimination of d.c. power supplies has intensified the demand for a.c. motors ; the simple and widely used three-phase induction motor does not meet requirements where speed control is necessary to ensure maximum production, and the three-phase commutator motor of the double-fed, Schrage, or series type can be economically used. While three-phase supplies are normally available wherever powers of more than about 5 hp are required, single-phase supplies are common for smaller outputs, and single-phase motors (particularly the single-phase induction motor) form, numerically speaking, a very large proportion of the total number of motors in existence.

Although the same basic principles govern all electrical machines and a general treatment can be developed to cover all types, it becomes necessary, beyond a certain point, to consider each machine separately, and in detail. In this excellent and authoritative book, such detailed consideration is given.

Part I covers matters common to all types of commutator motor, while the remaining three parts deal respectively with auxiliary machines for induction motors, three-phase commutator motors, and single-phase motors, including the single-phase induction motor. A number of relevant examples, with answers, is included at the end of each chapter.

A Practical Guide to The Design of Steel Castings. 56 pp., 121 illustrations. Published by The British Steel Castings Research Association, East Bank Rd, Sheffield 2. Price : 12/6.

As a result of having acquired from *Editions Technique des Industries de la Fonderie* the English translation rights of their French publication entitled " Guide Practique du Tracé des Pièces en Acier Moulé ", The British Steel Castings Research Association are now publishing this English version.

The book, well-conceived and profusely illustrated, deals with steel castings from the point of view of soundness, economy in production, and good engineering design. It is an up-to-date study of the problems of steel-castings design, and, as such, is of undoubted interest and value to designers, draughtsmen, engineers, steelfounders, students, and many others concerned with the specification, design, and production of cast-steel components.

Pumps, Fans, and Compressors. By A. de Kováts and G. Desmuir. 340 pp., 200 illustrations. Publishers : Blackie & Son Limited, 17 Stanhope Street, Glasgow, C.4. Price : 45/–.

Well-translated from the original French by R. S. Eaton, M.A., this excellent and authoritative book covers the design, construction, and operation of centrifugal and axial-flow pumps, fans, and compressors. Essentially, the book has a practical bias, assuming a knowledge on the part of readers of the fundamental laws of hydraulics, aerodynamics, and thermodynamics. In fact, the theoretical part of the book is restricted to those laws which are indispensable to a complete understanding of problems of design, but the phenomena of flow and of energy transformations are discussed in greater detail, as it is considered that the differences in behaviour of an actual fluid and an ideal fluid in their passage through a machine are so great that to neglect them in any way would make it impossible to design the machine or even to understand its operation under variable conditions.

There can be no doubt that this is a most valuable book for all practising engineers concerned with this important subject.

Basics of Digital Computers. By John S. Murphy. 416 pp., 470 illustrations (in three volumes). Publishers : John F. Rider Publisher, Inc., 116 West 14th Street, New York 11, N.Y. Price : $2.50 per volume, $6.95 per set ($7.95 in single cloth binding).

With the increasing importance and applications of digital computers, it is hardly surprising that there is a growing requirement on the part of those with only a rudimentary knowledge of electronics for a simple and easily assimilated exposition of the basic principles of electronic digital computers. This well-written and imaginatively presented book admirably fulfils this requirement, reducing, as it does, the fundamentals of the subject to essentials which are presented in an easy-to-read, " picture-book " form.

Volume I reviews the development of computers and then thoroughly explains the basic theory of computer arithmetic, data representation, programming, " and " and " or " circuitry, and control. Volume II discusses the logical elements, circuits, typical kinds of signals, and magnetic cores, which are then combined to show a number of units typical of computers, such as encoders, decoders, counters, and adders. Volume III covers the large-system aspects of computers, with separate discussions of types of memory, control systems, and input-output equipment, and an extended treatment of the subject of timing.

Air Conditioning and Refrigeration. By William H. Severns, M.S., and Julian R. Fellows, M.S. 576 pp., 285 illustrations. Publishers : John Wiley & Sons, Inc., New York, and Chapman & Hall, Limited, 37 Essex Street, London, W.C.2. Price : 82/–.

Based on the second edition of *Heating, Ventilating, and Air-Conditioning Fundamentals*, by Professors Severns and Fellows, this new book is a completely rewritten version of the original, with an added chapter on a fluid flow, a greatly expanded treatment of refrigeration, and the inclusion of nearly 100 new illustrations.

The authors' approach to the combined subjects of air conditioning and refrigeration is balanced and rational. Equations are either developed from known thermodynamic principles, or references are given to where the basic explanations can be found. One notable feature of this volume is its discussion of a complete procedure covering the design of an air washer. It also supplies the only presentation in book form of a technique for finding the enthalpy of the outdoor air to be used in computing cooling loads when the time of the peak load is other than 3 p.m. In addition, many comprehensive examples and problems are available, including problems on the design of hot-water heating systems, fan-duct systems, and all-year air-conditioning systems.

Although written principally as a textbook for undergraduate courses in mechanical engineering and in architecture, there can be no doubt that this excellent book is of considerable interest as a reference work for all engineers practising in this field.

Electrostatics. Edited by Alexander Schure, Ph.D., Ed.D. 72 pp., 29 illustrations. Publishers : John F. Rider Publisher, Inc., 116 West 14th Street, New York 11, N.Y. Price : $1.35.

Providing a concise, yet comprehensive and thorough, treatment of the principles of electrostatics, this excellent little book uses a simple mathematical treatment which enables students or technicians to obtain a definite understanding of the subject.

Specific attention is given to such topics as atomic structure, conductors and insulators, dielectrics and dielectric constants, charge distribution, capacitance and capacitors, and electric potential. Coulomb's Law, Gauss's Law, and others are explained, and the *cgs* and *mks* units systems are discussed. In addition, liberal use is made of worked-out examples, and a chapter is included on electrostatic applications, including the Van de Graaff generator.

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2. Steel Castings. A 16-page illustrated brochure describes a newly introduced method of producing steel castings, generally to fine limits, with new standards in the reproduction of detail and finish. While casting work concerned in the production of moulding tools for the plastic industry is dealt with, it is only indicative of a typical use for which the system may be adapted. Other applications which have proved equally successful include the production of die-casting dies, forging dies, tools, and intricate castings of varying types which are considered impracticable for production by normal foundry methods.

One of the important advantages of this system is that the satin surface finish of the castings is readily polished to a mirror finish, owing to the remarkable density of the castings. Coupled with dimensional accuracy, this finish eliminates slow and expensive die-sinking.

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Many materials are available for their construction, and selection is governed by both the working conditions and by the design of the cover itself. Particulars are given of four main types of bellows construction, end fixings, supports, ventilation, extension cords, and split covers, and useful information is included on the shape of covers, as well as on a new method of sealing a cover, intended to overcome many of the old disadvantages.

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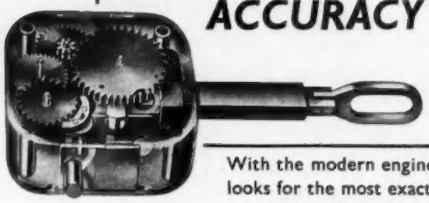

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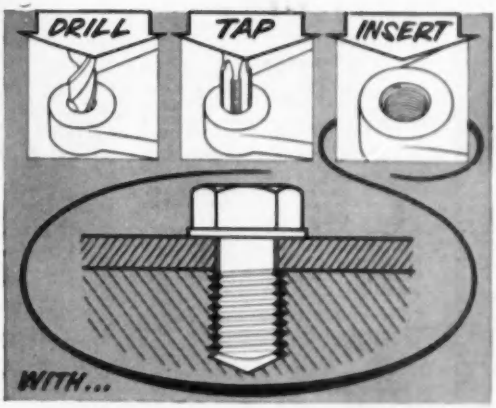

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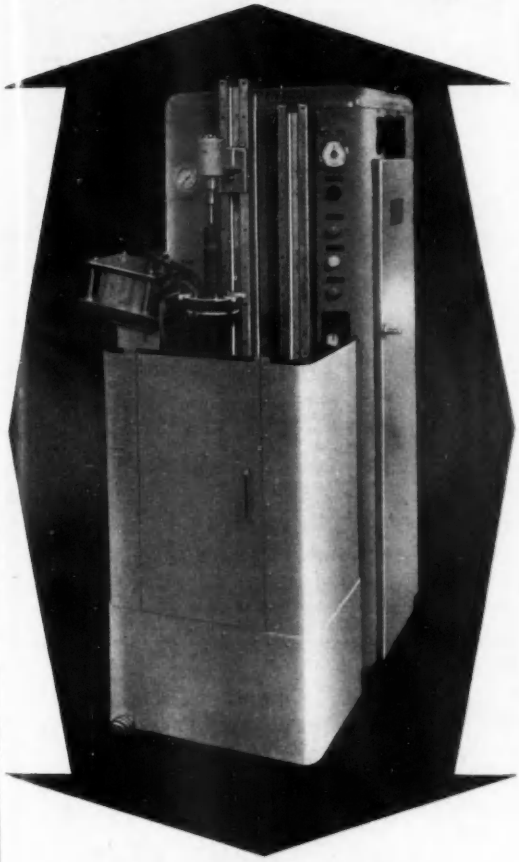

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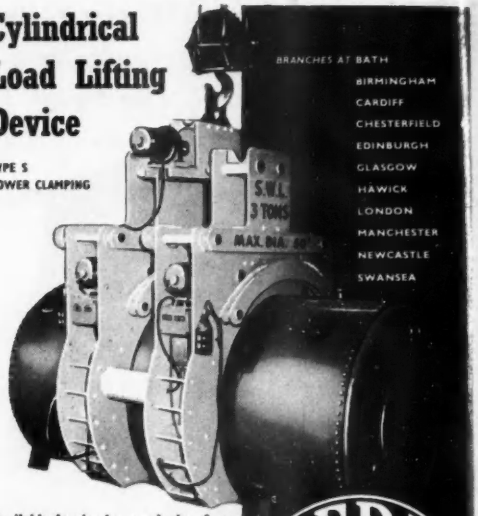

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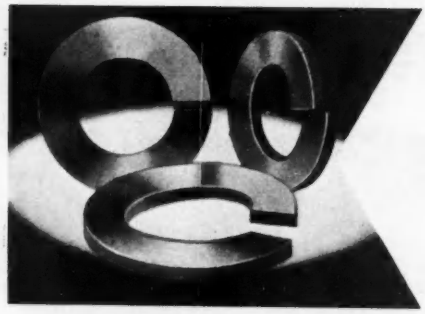

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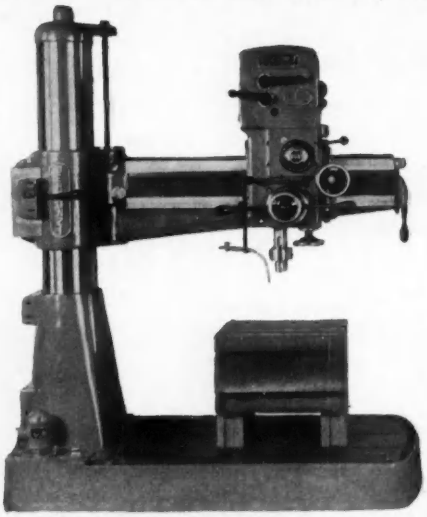

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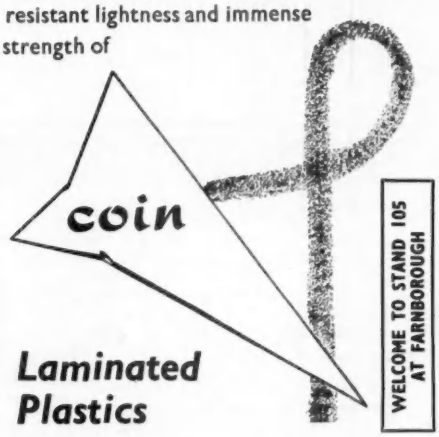

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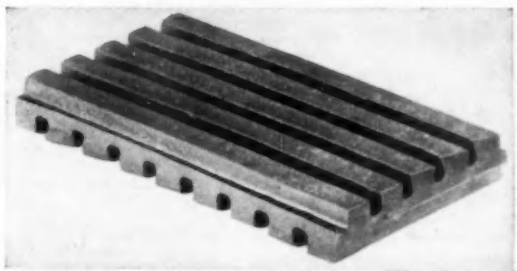

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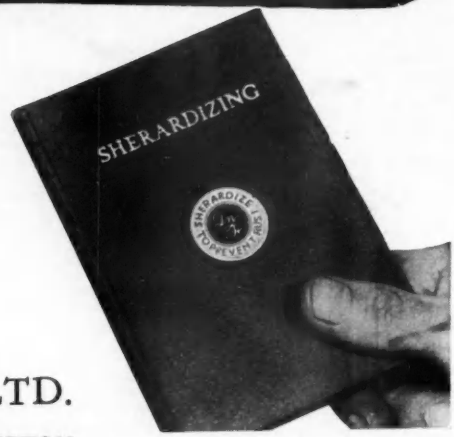

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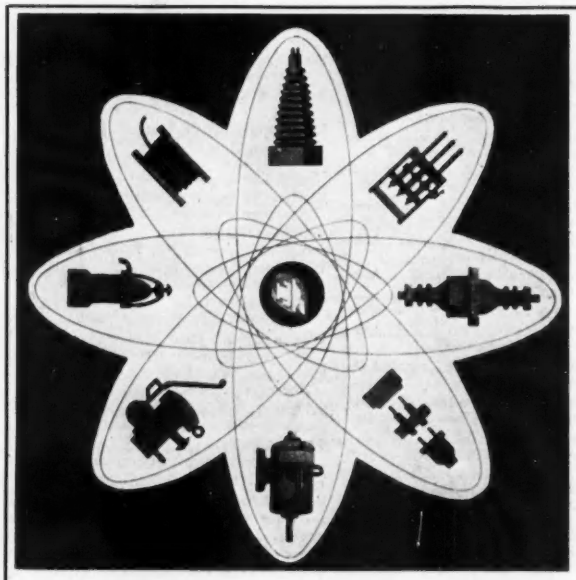

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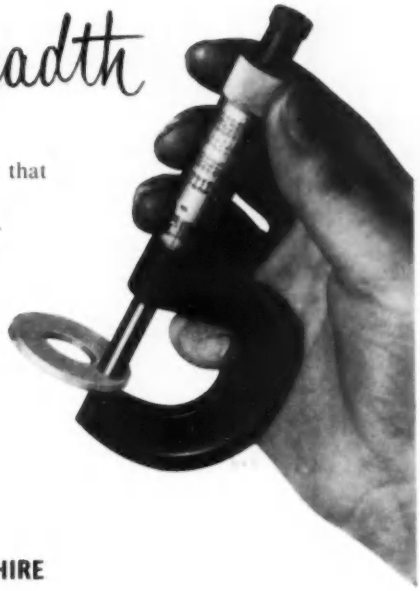

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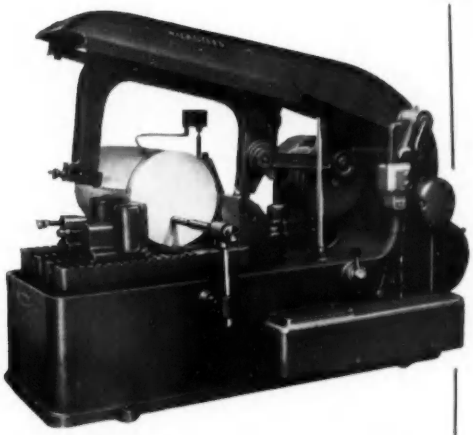

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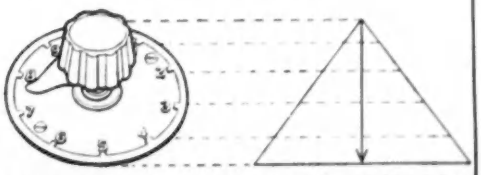

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